THE NATURAL HISTORY OF PLANTS

THE NATURAL HISTORY OF PLANTS

THEIR FORMS, GROWTH, REPRODUCTION, AND DISTRIBUTION

FROM THE GERMAN OF

ANTON KERNER VON MARILAUN

PROFESSOR OF BOTANY IN THE UNIVERSITY OF VIENNA

TRANSLATED AND EDITED BY

F. W. OLIVER, M.A., D.Sc.

QUAIN PROFESSOR OF BOTANY IN UNIVERSITY COLLEGE, LONDON

WITH THE ASSISTANCE OF

MARIAN BUSK, B.Sc. AND MARY F. EWART, B.Sc.

WITH ABOUT 2000 ORIGINAL WOODCUT ILLUSTRATIONS AND SIXTEEN PLATES IN COLOURS

DIVISIONAL VOLUME VI.

LONDON: BLACKIE & SON, LIMITED

GLASGOW, EDINBURGH, AND DUBLIN

CONTENTS OF DIVISIONAL VOLUME VI.

LIST OF ILLUSTRATIONS.

THE HISTORY OF SPECIES.—*Continued.*

CLASSIFICATION OF PLANTS PROPOSED BY THE EDITOR.

Each cell contains a single nucleus which occupies approximately the centre of the cell. In the larger species it is suspended in the middle of the vacuole by a number of branching threads, many of which run into the peripheral protoplasm opposite a pyrenoid. This can be particularly well seen in the large *S. crassa.* It suggests that the nucleus plays some active part in the function of starch formation. In the smaller species when the breadth of the cell is perhaps not more than double the diameter of the nucleus, the latter often lies in the concavity of, and in contact with, a chromatophore. In this case the protoplasmic threads are not so obvious.

All the cells of a *Spirogyra*-thread are capable of division. After the nucleus has divided, a rim of cellulose is secreted in the equatorial plane of the cell. This is gradually added to from within, till a complete disc of cellulose is formed, separating the two daughter-cells. Curious folds are always formed on the transverse walls of some species. Each fold forms a circular rim near the periphery of the transverse wall and projecting into the cell cavity. These folds are sometimes completely evaginated, the transverse wall thus having its surface considerably increased and becoming strongly concave towards the cell-cavity. This happens especially when two cells are separating from one another, or, when a gamete is formed from a neighbouring cell.

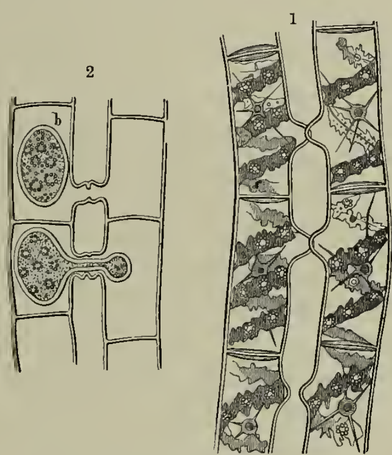


Fig. 373.—*Spirogyra.*
1 Two filaments commencing to conjugate.
2 Formation of zygotes.

Multiplication is often effected by the breaking up of a filament into segments consisting of a few cells each which go on dividing and form a new thread.

Conjugation takes place in two ways; a zygote being produced either from gametes formed in two neighbouring cells of the same filament, or in two cells belonging to distinct filaments. In the former case a small swelling is formed opposite a septum, a small area of the septum breaks down, and the contents of one cell, rounding itself off from the walls, passes through the aperture thus formed and fuses with the contents of the other cell, also rounded off, to form a zygote, which immediately puts on a membrane, and enters upon a resting stage.

In the second or "ladder-type" of conjugation (fig. 373, and Plate I., 1), two filaments come to lie side by side, and the contents of some or all of the cells of one thread round off, each cell-wall growing out into a short tube towards a cell of the other thread. Each cell of the other thread then either swells up towards this tube or puts out a similar tube, and the walls coming into contact are absorbed, an open canal (conjugation-canal) thus being formed between the two cells. The contents of the first cell then passes through the canal into the cavity of the second, the contents of which has also rounded off, and fusion occurs between the two gametes. The whole of the cells of two filaments frequently conjugate about the

same time, and the series of conjugation-canals thus formed give the appearance of the rungs of a ladder. All the zygotes are formed in one filament, which we may consider as physiologically female, its gametes being relatively passive compared with those of the other (male), which initiate the process, and actively pass through the canals. The relative behaviour of the two threads shows that an influence is exerted by the male on the female cell, the former determining the outgrowth and direction of the tube belonging to the latter, as well as the rounding off of the female gamete. If the female tube is not put out opposite the male, the former bends round to meet the latter, and if the male cell dies in the middle of the process, the female tube goes on growing indefinitely, and the female gamete does not round itself off. The influence exerted is in all probability a chemical influence, a phenomenon which seems to occur in connection with the process of the conjugation of gametes throughout the vegetable kingdom (*cf.* the remarks on pp. 68 and 413).

The chromatophore of the germinating zygote is formed from that of the female gamete alone, the band belonging to the male gamete gradually disintegrating in the zygote. This is an interesting example of the reduction of the specially vegetative portion of the male cell.

Zygnemaceæ.—The cell of *Zygnema* differs from that of *Spirogyra* (Plate I., m) in its remarkable and beautiful star-shaped chromatophores. There are two of these in each cell, occupying positions equidistant from the centre of the cell. Each possesses a rounded central portion, containing a single pyrenoid, from which thicker or thinner processes radiate in all directions. The nucleus forms a bridge between the two chromatophores.

Conjugation takes place much as in *Spirogyra*, the zygote being formed either in the conjugation-canal or in one of the conjugating cells.

Mougeotiaceæ.— This family is characterized by the possession of single axile plate-like chromatophores, and by the fact that part of the protoplasm of a conjugating cell does not enter into the formation of the zygote.

The chromatophore, which possesses a single row of pyrenoids, can alter its position according to the strength of the light to which it is exposed. In moderate light the plane of its surface is at right angles to the line of the incident rays, in stronger light it places itself in the same plane as these rays, so that they only fall upon its edge. In very strong light it contracts to form an irregular body in the centre of the cell.

In conjugation the cells of two threads either put out tubes, and form spherical zygotes in the conjugation-canals (*Mesocarpus*-type), or the two cells bend towards one another, and form a four-sided zygote, one side of which occupies the centre of each cell. The wall of the zygote thus cuts off the two ends of the two cell cavities, so that the zygote appears as if it were surrounded by four empty cells (*Staurospermum*-type). These, however, soon break off.

Gonatonema forms so-called aplanospores in the following way. A cell increases to double its former length, its contents (chromatophore, &c.) dividing into two parts. A swelling is formed in the middle of the cell, into which the two chromato-

phores and the bulk of the protoplasm move from each end. A wall is now formed round the contents of this swelling. Although the behaviour of the nucleus has not been followed, this certainly suggests a reduced process of conjugation, each half of the cell representing a gamete.

Mougeotiopsis is a genus whose chromatophore possesses no pyrenoids.

Alliance X.—Charales.

Family: *Characeæ*, the Stoneworts.

Are green submerged plants with segmented axes bearing whorls of leaf-like appendages at the nodes, upon which the antheridia and oogonia are borne. The antheridia are spherical and contain a large number of filaments, each cell of which produces a spermatozoid with two long cilia. The oogonium consists of an egg-cell inclosed in five spirally-twisted, tubular cells; on germination the egg-cell gives rise to a simple segmented filament (the pro-embryo) from which the adult form arises as a lateral bud. There are no swarm-spores. Vegetative propagation is by bulbils, detached branches, &c. This alliance, though placed here in sequence with the other alliances of Green Algæ, is probably remote from them in actual affinity. The Charales form an isolated and anomalous group, and various views are entertained as to their true position.

Members of this group occur very commonly in ditches, ponds, &c., and in brackish water. In the Norfolk Broads very extensive growths of these plants occur in the muddy bottom of the Broads, the living plants resting on the decomposing remnants of former generations; in this way the bottom level is being gradually raised.

Chara fragilis (see fig. 374) is perhaps the commonest species of the group, and is cosmopolitan in its distribution. The plant is some 12 inches high, and consists of axis with whorled leaf-like appendages inserted at the nodes. The axis consists of a number of long cells (the internodal cells) with which alternate the short nodal cells. The former remain undivided, whilst the latter originate the appendages and also a number of tubes, which, growing both upwards and downwards, everywhere cover in the internodal cells, forming a sort of cortex. The "leaves" have a structure essentially similar to that of the stem; they are, however, of limited growth (fig. 374^3). They bear at their nodes tiny leaflets and the reproductive organs. The oogonia and antheridia occur together in this species (figs. 374^2 and 374^3), the latter below the former. The antheridia are spherical orange-coloured bodies, consisting of eight shields or plates whose edges dovetail into one another; each bears a process (the manubrium) on its inner surface, and each of these manubria bears a tuft of filaments (fig. 374^5), in every cell of which a coiled spermatozoid is produced bearing 2 long cilia at the tip (figs. 374^6 and 374^7). The shields now disarticulate and the spermatozoids escape. The oogonia (or amphigonia) remotely resemble the archegonia of Ferns (*cf.* fig. 346^2, p. 472). Each contains a big oval egg-cell inclosed in a sheath of 5 tubes spirally wound around it. The tips of these tubes

form a crown surmounting the oogonium (fig. 374[8]). At fertilization the spermatozoids penetrate between the cells of the crown, so reaching the egg-cell. The whole oogonium is soon detached and remains dormant through the winter. In the spring it germinates, pushing out a tube which becomes transversely segmented. This is the pro-embryo. From it, as a lateral bud, the adult sexual plant arises. This process resembles that of the Mosses, in which the leafy Moss-plant arises from

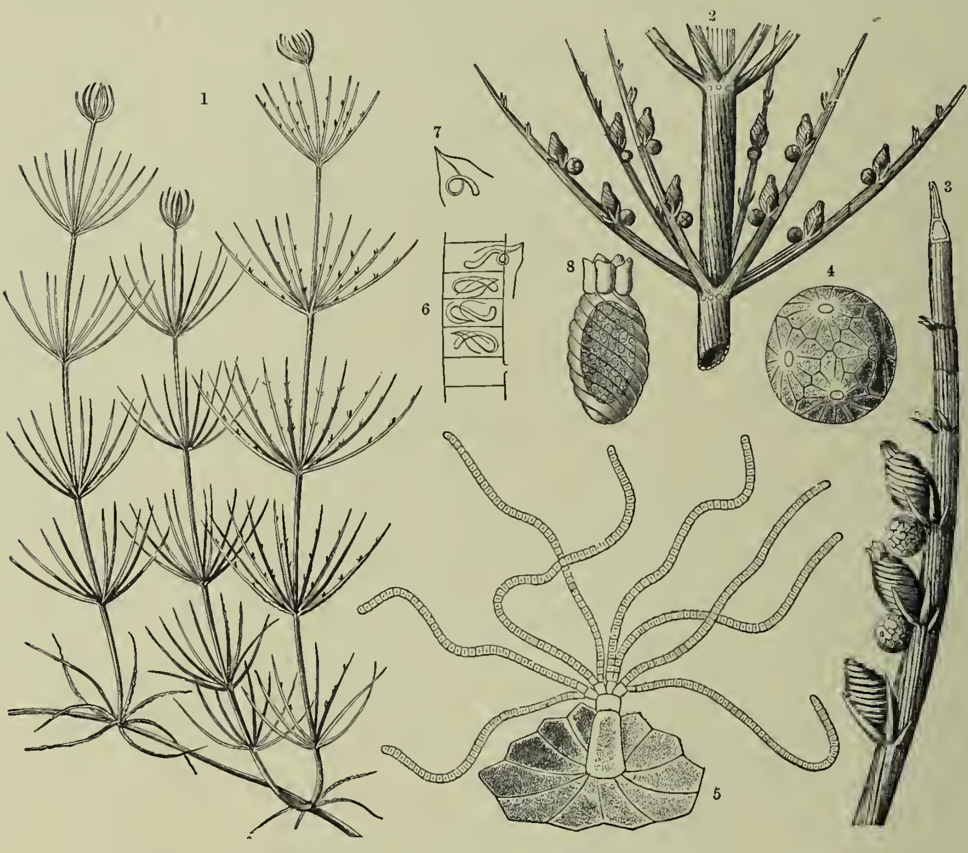


Fig. 374.—Structure and reproduction of *Chara fragilis.*

[1] A portion of the plant. [2] A piece of the axis with appendages, upon which are inserted the sexual organs. [3] A single appendage, showing the flask-shaped archegonia and spherical antheridia. [4] A single antheridium. [5] A plate of an antheridium with manubrium and whip-like filaments of cells containing spermatozoids. [6] Several cells from one of the whip-like filaments: the cells in the middle contain each a spermatozoid; the spermatozoid is escaping from the uppermost cell; the lowest cell is already vacated. [7] A single spermatozoid. [8] Archegonium inclosing the egg-cell. [1] nat. size; [2] ×10; [3] ×15; [4] ×35; [5] ×100; [6] ×300; [7] ×500; [8] ×50.

the protonema as a lateral bud. But the comparison with Mosses must not be pushed too far, as in *Chara* there is no sporogonium. There are some 67 species of *Chara,* of which *C. fœtida* is also very common. Many of them are covered with stiff hairs, and they are for the most part brittle owing to the incrustation of carbonate of lime (*cf.* vol. i. p. 260). The phenomenon of parthenogenesis in *Chara crinita* has already been described in detail (pp. 463, 464).

In *Chara stelligera* (= *Tolypellopsis ulvoides*) the nodes of the stem become

swelled out with starch, and assume a stellate form (starch-stars). They serve as organs of vegetative propagation.

The other large genus of Characeæ is *Nitella.* It is especially distinguished by the fact of its stems and leaves being destitute of cortex. There are 67 species of *Chara* and 77 of *Nitella.*

Characeous fruits (*Gyrogonites*) are met with in large numbers in the lower chalk and in tertiary formations. Only rarely are fragments of the stems, &c., recognized.

Alliance XI.—Phæophyceæ.

Families: *Ectocarpaceœ, Sphacilariaceœ, Cutleriaceœ, Laminariaceœ, Fucaceœ.*

Includes the whole series of the Brown Sea-weeds, essentially characterized by the fact that their chlorophyll-corpuscles include, in addition to chlorophyll, a brown pigment, Phycophæin, which masks the green colour of the chlorophyll. The forms included under this alliance are all multicellular, and range from simple threads of cells to large complex forms showing a differentiation into a root-like attachment-organ, stipe, and expanded leaf-like frond. In several of these larger forms the internal structure almost rivals that of Flowering Plants in complexity. Within the limits of the group we find sexual reproduction, in some cases by the fusion of equivalent motile gametes (*cf.* p. 50), in others of well-marked egg-cells or spermatozoids. Fertilization and the complete life-history has been studied in relatively few cases.

Ectocarpaceœ.—These are mostly filamentous and often branched. Attached to the branches are the sporangia and gametangia. From the former motile zoospores are liberated. From the latter similar bodies—the gametes—are liberated. These possess two cilia, attached *laterally* to the gametes. The process of fertilization has been followed in *Ectocarpus siliculosus.* Certain of the gametes come to rest first, and these are approached by a number of other gametes, which swarm around them. Ultimately one of the swarming gametes fuses with the resting gamete and fertilizes it. This process has been thought to indicate the existence of a certain sexual differentiation amongst the gametes, the gamete which comes to rest first being the egg-cell. However, there is no demonstrable structural difference between them.

Sphacelariaceœ.—The filaments consist of many layers of cells. Reproductive organs agreeing in the main with the last-named family.

Cutleriaceœ.—Mostly branched, ribbon-like forms. The gametangia are arranged in tufts, and the gametes differ in size, but both possess two cilia.

Laminariaceœ.—Perhaps the most interesting family of the alliance. Many forms are known to liberate motile reproductive cells from various portions of their surface, but the fate of these bodies has not been ascertained. They are large marine forms, some of them attaining gigantic dimensions. *Laminaria digitata,* which grows in quantities near low-water mark on our coasts (where it forms a regular "Laminaria-zone"), has a tuft of powerful roots holding it to the rocks, a long

stipe, and a flat, expanded leaf, deeply lobed like a hand. It is often met with two metres in length. The leaf is of a leathery consistency, and the flattened or cylindrical stalk has a wide parenchymatous cortex and central "medulla", in which run curious tubes (the "trumpet hyphæ") which swell out at intervals, the swelling being traversed in a transverse direction by a delicate sieve-plate. The stem possesses a peripheral cambium-like zone, which adds each year a new zone of tissue to the cortex. The stems, which are sometimes found much thicker than one's

Fig. 375.—Laminariaceæ, with perforated fronds.

1 *Agarum Gmelini* (after Riocreux). 2 *Thallasiophyllum clathrum* (after Postels and Ruprecht). Both much reduced.

thumb, show in section a series of rings, reminding one of the annual rings of a dicotyledonous stem. A long ribbon-like form, *L. saccharina,* is also common on our shores. In other forms the frond is branched and often curiously appendaged at the base. In the two genera represented in the accompanying illustration (figs. 375 1 and 375 2) *Agarum* (from the North Atlantic) has a simple, *Thallasiophyllum* (North Pacific) a compound frond. In both the fronds are perforated or fenestrated. *Lessonia* (Southern Pacific) attains to tree-like dimensions and is much branched; it has a stem as thick as a man's thigh. But the two most impressive genera are *Macrocystis* and *Nereocystis.* The former, which occurs throughout the southern oceans and on the western coast of N. America, consists of a long stalk, sometimes attaining a length of 300 metres, but in thickness not exceeding a penholder. To

this stalk are attached a series of long ribbon-like leaves, each of which, just at its point of insertion upon the stem, swells into an air-bladder about the size of a pigeon's egg. Thus the stem, which is attached below, is buoyed up, and the long leaves depend into the water. In structure the stem is not unlike that of a *Laminaria*; but it possesses in addition to the medulla, with its trumpet hyphæ, a zone containing large sieve-tubes, which resemble those contained in the soft bast of a Flowering Plant (*cf.* vol. i. fig. 10[4], p. 45, and fig. 125[7], p. 469). *Nereocystis*, occurring on the W. coast of N. America, consists of a long stalk (attaining to a length of nearly 100 metres), attached at its lower extremity and expanding above into a huge retort-shaped air-sac, from the surface of which a number of fronds (6–10 metres in length) arise. Like *Macrocystis*, its stem contains well-marked sieve-tubes. It is used by the Aleutians as fishing-line. Of Laminariaceæ about 90 species have been distinguished (including 30 species of *Laminaria*).

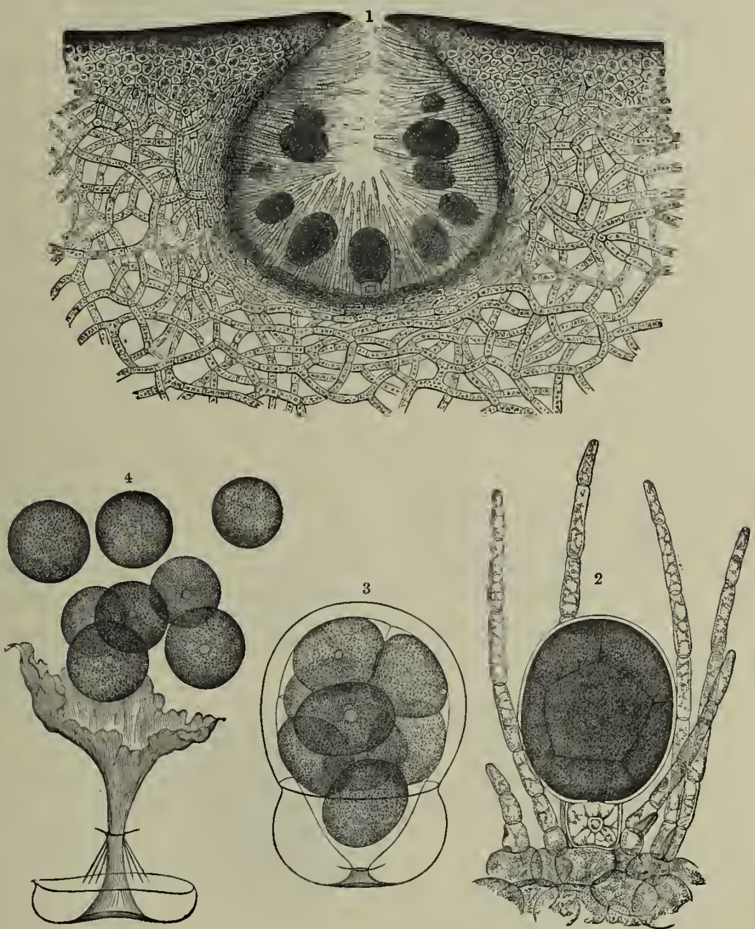


Fig. 376.—*Fucus vesiculosus.*

1 Vertical section through a female conceptacle. 2 A single oogonium from the conceptacle surrounded by sterile hairs. 3 A detached oogonium containing 8 egg-cells; the inner lamella of the wall is much swollen. 4 Liberation of the egg-cells. $^1\times 50$; $^{2,3,4}\times 160$. (After Thuret.)

Fucaceæ.—Includes a number of the larger common sea-weeds. They are characterized—like the last family—by a segmentation into a well-marked shoot and organ of attachment. The former is usually flattened and branched, and often bears air-bladders. Reproduction is by means of spermatozoids and non-ciliated egg-cells, which arise in flask-shaped hollows (conceptacles) on definite portions of the shoot or frond. Asexual reproduction by detachment of fragments.

The Wrack-genus *Fucus* forms an exceedingly conspicuous feature of our seashore flora. The shoot is flattened and ribbon-like, branching in one plane and attached to stones, &c., by a sucker-like disc. In many species there is a midrib, as also air-bladders. The tips of many of the branches are studded with little rugosities — really indicating the presence of pear-shaped hollows, the conceptacles. From the lining of these conceptacles project the oogonia and branched filaments bearing antheridia respectively. As a rule the male and female organs occur on distinct plants, though in some species the antheridia and oogonia occur side by side in the same conceptacle. The structure of the sexual cells and the act of fertilization (which occurs outside the mouth of the conceptacle) have been fully described on pp. 51, 52; they are represented in figs. 376 and 377. Sixteen species of *Fucus* are distinguished, and they occur for the most part in the seas of the northern hemisphere. *Fucus vesiculosus* and *F. serratus* are the commonest. Several other genera are represented in Britain, *Pelvetia, Ascophyllum, Cystoseira, Halidrys,* and *Himanthalia.* The last-named genus is altogether peculiar, and consists of a top-shaped body attached by its pointed end, whilst from the upper surface of the "top" arise several ribbon-like outgrowths which branch repeatedly and attain to a length of several metres. It is upon these ribbons that the conceptacles are borne. Of exotic forms a few may be mentioned. *Durvillæa* from the southern seas resembles a thick, fleshy *Laminaria* in habit; from the summit of its thick stipe arise a

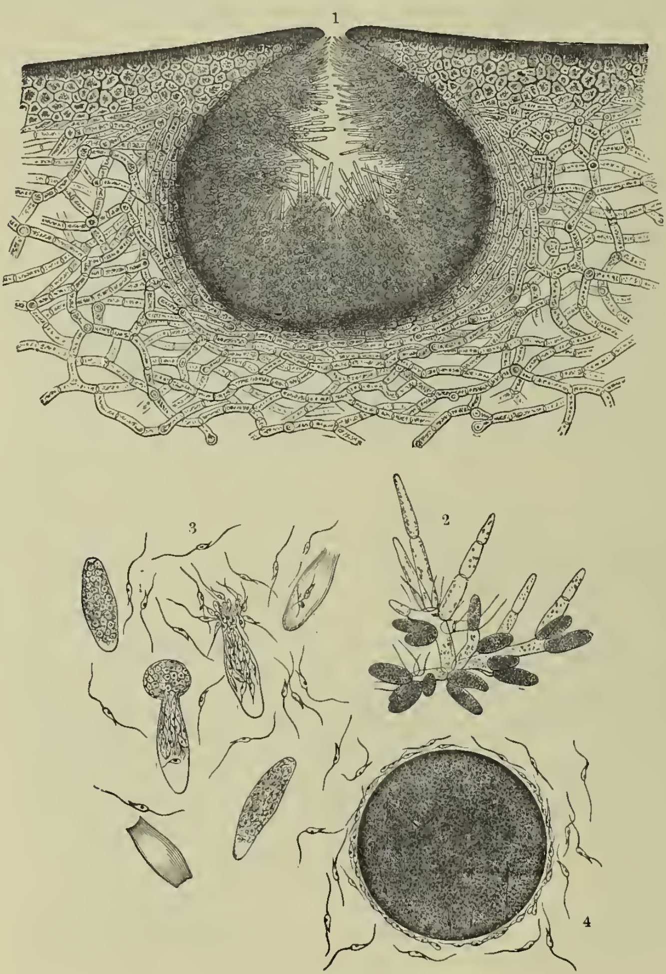


Fig. 377.—*Fucus vesiculosus.*

1 Vertical section through a male conceptacle. 2 A portion of one of the shrubby, branched hairs bearing antheridia. 3 Spermatozoids escaping from the antheridia. 4 Spherical egg-cell with spermatozoids attached. $^1\times 50$; $^2\times 160$; $^{3,4}\times 350$. (After Thuret.)

number of irregular fleshy lobes, which are produced into branching, whip-like filaments. Its tissues possess a curious honey-combed structure. It is stated that in Chili, &c., *D. utilis* is used as an article of food. *Sargassum* is distinguished by its high differentiation. It has cylindrical stalks bearing leaf-like appendages, and little stalked spherical air-bladders, and receptacles for the sexual organs. Some 150 species of this very varied genus are known, scattered over the warmer zones of the world. Particular interest attaches to the Gulf-weed (*Sargassum bacciferum*, fig. 378) which forms the chief component of the floating masses of Sargassum in certain regions of the Atlantic. The Sargasso Sea has received its name from the enormous amounts of this floating weed which are met with there. It occupies an area in the Atlantic perhaps equal to that of the continent of Europe. There are two main accumulations, the larger south-west of the Azores, the smaller situated between the Bermudas and Bahamas, whilst connecting them is a narrow belt. The exact nature of these accumulations is not ascertained. According to one view the Gulf-weed actually lives a pelagic life, growing and multiplying in this huge eddy in mid-ocean, and is thoroughly adapted to its special environment; whilst, on the contending hypothesis, the vegetation of the Sargasso Sea is purely ephemeral, does not reproduce, and is constantly renewed by ocean currents, which bring with them countless fragments forcibly torn by tempests from the shores of Florida and the Bahamas. It is further alleged that the floating Gulf-weed is met with only in a condition more or less unhealthy (moribund) and in various states of decomposition.

Fig. 378.—A branch of the Gulf-weed, *Sargassum bacciferum*, with leaves and air-sacs.

The weak point in the latter hypothesis is the lack of convincing evidence to show that *S. bacciferum* grows attached in the region of the West Indies, &c., in quantity sufficient to supply the Sargasso Sea. Of another species, *S. vulgare*, there is plenty, but this is not the prominent constituent of the Sargasso Sea—indeed a trained algologist, in passing recently through this sea, examined samples amounting to more than a ton, but it was only *S. bacciferum* he found. Here, evidently, is still matter for the leisured naturalist.

Over 300 species of Fucaceæ (including 150 Sargassums) have been distinguished.

Alliance XII.—**Dictyotales.**

Family: *Dictyotaceæ.*

A small group of Brown Sea-weeds distinguished by the fact that both egg-cells and spermatozoids are destitute of cilia. The sexual cells are contained in club-shaped vesicles, inserted in tufts on the surface of the plants. Asexual reproductive cells ("tetraspores") are formed in sporangia in fours. They include the common *Dictyota dichotoma* and the beautiful iridescent fan-like *Padina pavonia.*

Alliance XIII.—**Florideæ**, Red Sea-weeds.

Aquatic, for the most part marine, plants, which contain in addition to chlorophyll a red or purple pigment, *phyco-erythrin*; the pigment, as in the brown sea-weeds, is confined to definite corpuscles. Reproduction is by means of asexual spores (tetraspores), and sexually by non-ciliated spermatia and procarps.

With the exception of *Batrachospermum, Lemanea,* and one or two other genera, the Florideæ are marine organisms and inhabit on the whole a deeper zone than any other sea-weeds. Several views prevail as to the significance of the red pigment. As has been already indicated (vol. i. p. 390) the rays of light, useful in ordinary chlorophyll-assimilation, are soon absorbed, as white light traverses considerable strata of water. Such light as penetrates some distance from the surface is preponderatingly blue, and, as is now known, such rays are actually destructive of vegetable protoplasm. It may well be then that the red pigment serves to screen the protoplasm from the action of these rays, permitting the chlorophyll to make use of such of the red rays as filter to it; or—what is more probable—the red pigment is itself an assimilating pigment, either directly absorbing the blue rays and allowing the protoplasm of the chlorophyll-corpuscles to use their energy for building up complex food-materials, or indirectly (as indicated at vol. i. p. 390) by altering their wave-length they are made serviceable to the chlorophyll-corpuscles.

The Florideæ exhibit an enormous variety of form, and almost all of them are attached. There are the delicate cell-filaments of the *Callithamnions,* the corticated *Polysiphonias* and *Ceramiums* so common on our coasts, the fleshy cylindrical *Gracilarias* and *Polyides,* the flat and lobed *Chondrus* and *Gigartina,* the leathery *Iridæa,* and a host of others. One of the most beautiful of British genera is *Delesseria,* with its creeping stalk and crimson leaves with midribs and veins. In some species the leaves are entire, in others their margins are sinuous and lobed. Of all red sea-weeds perhaps the Australian *Claudea* holds the palm for beauty with its large latticed, rose-pink fronds. Certain groups, *Corallina, Melobesia, Lithothamnion,* &c., are encrusted with large amounts of carbonate of lime, and build regular banks and reefs under the sea. In all there are some 280 genera and 1800 species of Florideæ.

Reproduction by means of asexual spores is a common phenomenon in the group. These spores, though not invariably, are most frequently formed in clusters of four,

and are termed *tetraspores*. In the simpler forms they arise in little projecting sporangia, in other cases they are on specialized branches or embedded in the substance of the frond.

The sexual organs, however, are very remarkable, and differ from those of other Thallophytes. The male cells arise from clusters of cells (antheridia) at the tips of branches or in groups upon the surface of the frond. Each antheridium liberates a single, non-ciliated male cell termed a *spermatium*. The female organs or *procarps* consist of a filamentous receptive organ, the trichogyne, and a basal part, the *carpogonium* (*cf.* figs. 204^7 and 204^8, p. 53). Besides the carpogonium there are *auxiliary cells*, to be described directly. The process of fertilization has been followed in detail in *Nemalion* since the earlier portions of this volume passed through the press, and we now know that the suggestion of an osmotic fertilization in the Florideæ (*cf.* p. 60) is erroneous. The spermatium becomes attached to the trichogyne, and at this point the wall of the trichogyne is absorbed. The nucleus of the spermatium enters the trichogyne and travels down it to the carpogonium at the base, where it fuses with the carpogonial nucleus. The carpogonium now divides, giving rise to a mass of spores (the carpospores). In other cases the process is less simple. As before there is a trichogyne and carpogonial cell, but associated with the latter a number of auxiliary cells. The carpogonium when it is fertilized does not give rise at once to a mass of spores, but enters into a process of conjugation with these auxiliary cells, and from them the carpospores arise. This conjugation may be an immediate fusion, or may be brought about by the instrumentality of special tubes. Thus we may suppose the fertilizing influence to be transmitted. In some cases (as in *Dudresnaya*) this may take place over considerable distances, from branch to branch. In the simpler forms the procarps are modified branches projecting freely into the water; in the more fleshy and ribbon-like forms they are sunk in hollows on the thallus and often associated with a large number of auxiliary cells. The trichogyne projects into the water through a small pore in the portion of the surface which roofs over the procarp and auxiliary cells. As a result of fertilization of the carpogonium and its conjugation with the auxiliary cells, a large mass of carpospores arises, which raises up the surface like a blister.

Fossil remains of red sea-weeds occur under the name of Nullipores. These are the calcareous incrustations of the *Corallinas, Melobesias, Lithothamnions*, &c., mentioned above. They occur in both the secondary and tertiary rocks. The Leitha limestone, largely used for building purposes in Vienna, comes from extensive nullipore banks in the Leitha Mountains, south-west of Vienna on the Hungarian frontier, and, just as in Paris many of the finest buildings are constructed of the consolidated calcareous remains of Foraminiferæ, so in Vienna are the incrustations of certain red sea-weeds put to this purpose.

Class V.—FUNGI.

Parasitic or saprophytic plants destitute of chlorophyll and for the most part possessing a mycelium. Sexual reproduction known and generally admitted in the Phycomycetes only. Asexual reproduction by means of spores and conidia.

Sub-class I.—Phycomycetes.

Mycelium for most part unicellular, tubular, and branched. Sexual reproduction both by conjugation of equivalent cells and by egg-cells.

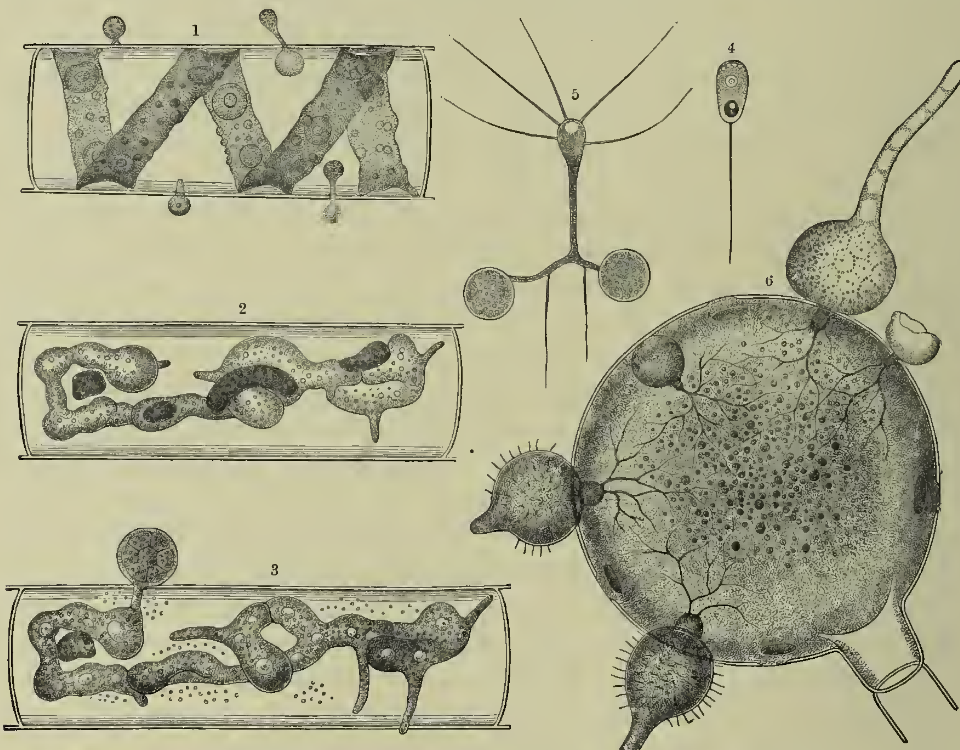


Fig. 379.—Chytridiaceæ and Ancylistaceæ.

1, 2, 3 *Lagenidium Rabenhorstii*, parasitic upon *Spirogyra*. 4, 5 *Polyphagus Euglenæ*. 6 *Rhizidiomyces apophysatus*, parasitic on an oogonium of *Saprolegnia*.

Alliance XIV.—Oomycetes

Families: *Peronosporeæ, Saprolegniaceæ, Chytridiaceæ, Ancylistaceæ, Entomophthoreæ.*

Mycelium often very slightly developed; asexual reproduction by means of swarm-spores; sexual reproduction by egg-cells. On the whole in this group we are dealing with Fungi which very nearly resemble the Algæ of the Alliance Siphoneæ (e.g. *Vaucheria*) both as regards the structure of their mycelium and mode of reproduction. A loss of sexuality is to be noted in many members of this group.

Peronosporeæ.—Are mostly parasitic upon Flowering Plants, and the cause of many destructive diseases. They establish themselves by means of a branching, tubular, non-septate mycelium which penetrates the intercellular system of the host-plant (*cf.* p. 56). They propagate asexually by means of unicellular sporangia borne on branched hyphæ which project from the stomates, &c., of the host (*cf.* fig. 381[2]); these sporangia (or spores as they are sometimes termed) liberate on a moist substratum a number of swarm-spores (figs. 381[4,5,6]) which originate new plants.

Fig. 380.—Swarm-spores in Saprolegniaceæ and Chytridiaceæ.

[1] *Achlya prolifera.* [2, 3, 4] Successive stages of swarm-spore-formation in *Achlya prolifera.* [5] *Chytridium Olla*, parasitic on the oogonium of the Alga *Œdogonium*; development of swarm-spores. [6] *Saprolegnia lactea.* [7] Development of swarm-spores in the same. (Partly after De Bary and Pringsheim.) [1] ×20; [2, 3, 4] ×400; [5] ×300; [6] ×100; [7] ×300.

Sexual reproduction also takes place by the formation of oogonia and tube-like antheridia. The latter become attached to the former (fig. 381[3]), and, putting out fertilizing tubes which penetrate to the egg-cell within the oogonium, transmit their spermatoplasm. No spermatozoids are differentiated, but the spermatoplasm travels *en masse.* The fertilized egg-cell enters on a resting stage, and when it germinates may either give rise to swarm-spores (e.g. *Cystopus*) or grow at once into a new plant (*Pythium, Peronospora*). To *Phytophthora infestans* is due the well-known Potato-disease. The Fungus attacks the foliage and reproduces abundantly asexually. Later, its mycelium penetrates to the tubers and passes into a dormant state there. Consequently when stored these potatoes go bad, and if

used for planting are liable to reproduce the disease next year. Sexual reproduction is as yet not certainly known to occur in the life-history of the Potato-disease Fungus. *Phytophthora omnivora* and *Pythium de Baryanum* attack and destroy many young seedlings, causing them to "damp off". Various species of *Peronospora* are known which attack large numbers of cultivated plants. *P. parasitica* works havoc amongst the Cruciferæ; *P. viticola* (=*Plasmopara viticola*, fig. 381) has been referred to as a deadly disease on the Vine; *P. Viciæ* on various leguminous

Fig. 381.—The False Vine-mildew, *Peronospora viticola.*

[1] A bunch of grapes attacked by the False Vine-mildew. [2] Spores or conidia on branched hyphæ projecting from a stoma of a Vine-leaf. [3] Fertilization. [4] A single conidium. [5] Swarm-spores arising within the conidium. [6] A single swarm-spore. [1] nat. size; [2] ×80; [3–5] ×350; [6] ×380. ([3–6] after De Bary.)

crops; *P. Hyoscyami* on Tobacco-plants, besides which there are many others. The effects of *Cystopus candidus* have already been mentioned (p. 525); it is common upon cruciferous plants.

About 100 species of Peronosporeæ have been distinguished.

Saprolegniaceæ.—Are all aquatic and for the most part saprophytic; a few are parasitic on fish. In structure they much resemble Peronosporeæ. Swarm-spores are liberated in large numbers from the enlarged ends of the hyphæ (fig. 380). Sexual organs arise much as in Peronosporeæ, but although the antheridia develop fertilizing tubes in several instances, no case has been observed in which an actual transfer of spermatoplasm occurs. As a rule several or many egg-cells are produced

in the oogonia (fig. 382), and these germinate parthenogenetically. Although the sexual organs are still preserved in this group their function has been lost, leading the way to their complete atrophy in many other groups of Fungi. Many members of the group occur upon the bodies of dead insects and fish (*e.g.* various species of *Saprolegnia, Achlya, Aphanomyces*). *Aphanomyces phycophilus* is parasitic upon Algæ (e.g. *Spirogyra*) and *Saprolegnia Ferax* upon Salmon, &c.

About 45 species have been distinguished.

Chytridiaceæ.—Small parasitic aquatic Fungi whose mycelium is almost entirely wanting; they produce characteristic sporangia which liberate uniciliate swarm-spores. *Polyphagus Euglenæ* develops a very delicate mycelium, of which the branches become attached to Euglena-cells (fig. 379 [5], two Euglenas are thus attacked), and from the central portion of the mycelium arises a sporangium from which uniciliate swarm-spores (fig. 379 [4]) are liberated. These in turn germinate, develop threads, and entangle fresh Euglenas. *Rhizidiomyces* attacks the oogonia of Saprolegnias, sending a branching mycelium into their interior (fig. 379 [6]) and producing a pear-shaped sporangium at the surface which liberates numerous swarm-spores. *Chytridium Olla* (fig. 380 [5]) produces its sporangia on the oogonia of *Œdogonium*; its swarm-spores escape by the removal of a lid.

Fig. 382.—*Achlya lignicola.*

[1] Oogonia with antheridia and fertilizing tubes; no fertilization happens, however. [2] An oogonium containing egg-cells which have put on cell-walls without being fertilized. [1] and [2] × 400. (After Sachs.)

Over 180 species are known.

Ancylistaceæ.—Very nearly resemble the Chytridiaceæ in mode of life, but differ in exhibiting sexuality. *Lagenidium Rabenhorstii* attacks cells of *Spirogyra*, &c. The spores become attached to the *Spirogyra*-cells, and penetrate the wall (fig. 379 [1]) by means of a tube which branches about within, forming a lobed, irregular body (fig. 379 [2]), which may open at the outside, liberating swarm-spores (fig. 379 [3]), or sexual organs may arise inside and fertilization take place.

14 species have been distinguished.

Entomophthoreæ.—A group of forms almost all of them parasitic on insects. They are adapted to non-aquatic life, and connect the Peronosporeæ with the Zygomycetes.

The tubes of these parasites having effected an entrance into the body of an

insect, bud and sprout there with great activity. *Entomophthora radicans* commonly attacks caterpillars of the Cabbage-white (*Pieris Brassicæ*). Having spread through its interior, it sends out tufts of hyphæ on the ventral side (fig. 383 [1]), thus rooting the caterpillar to the substratum. It now develops hyphæ all over the body wrapping up the caterpillar like a mummy (fig. 383 [2]). At the tips of these hyphæ conidia are abstricted and shot off to some little distance (figs. 383 [3, 4, 5]). A con-

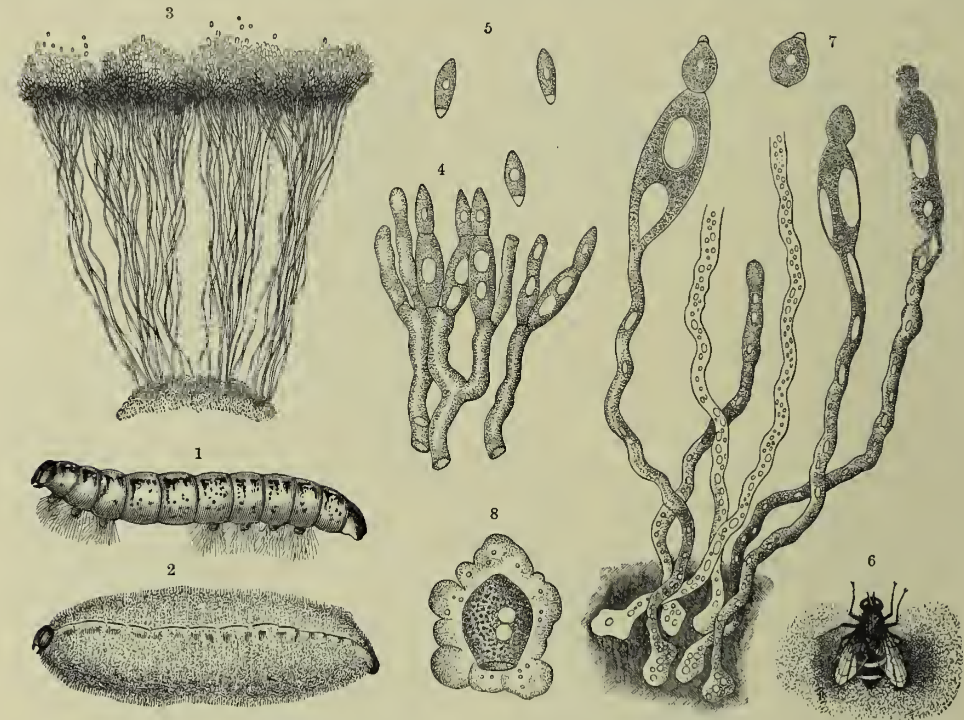


Fig. 383.—Entomophthoreæ: *Entomophthora* and *Empusa*.

[1] A caterpillar of the Cabbage-white Butterfly attacked by *Entomophthora radicans*. [2] The same caterpillar fully invested by the Fungus. [3] Tufts of conidia-bearing hyphæ from the back of the caterpillar. [4] Conidia separating from the tips of the hyphæ. [5] Disarticulated conidia. [6] A Fly attacked by *Empusa Muscæ*. [7] Hyphæ of *Empusa Muscæ*, from the tips of which conidia are being shot off. [8] Conidium inclosed in sticky mucilage. [1, 2, 6] nat. size; [3] ×80; [4, 5, 7] ×300; [8] ×630. (After Brefeld.)

jugation of branches sometimes occurs, whilst in other cases fruits are formed parthenogenetically. *Empusa Muscæ* produces a disease common amongst flies in the autumn. The Fungus having effected an entrance into the body of a fly gradually fills it up with its sprouts. In due time tubes penetrate the surface and develop conidia at their extremities (fig. 383 [7]). These are shot off as in the last case, and one may often see flies stuck to the window-pane in autumn surrounded by a halo of these conidia (fig. 383 [6]).

About 80 species of Entomophthoreæ are known.

Alliance XV.—Zygomycetes.

Families: *Mucoraceæ, Mortierelleæ.*

Are mould-like saprophytes with a much-branched, non-septate mycelium, sexual reproduction by conjugation; swarm-spores never met with. The common *Mucor Mucedo* (fig. 384) may be regarded as typical of this group. Its mycelium establishes itself on the substratum, and develops long-stalked sporangia at various points on its surface (fig. 384 [1]). In each sporangium (fig. 384 [2]) numerous spores are contained, and these can germinate, producing new mycelia on a suitable substratum. A conjugation of branches of the mycelium leading to the production of a fruit or zygospore (fig. 384 [3]) occasionally takes place, but the sexual method of reproduction is much commoner in other members of the group (*cf.* pp. 53, 54). The zygospore (or zygote) is invested in a strongly thickened membrane and can remain dormant for a considerable period. The hyphæ in many of the Mucors can break up into continuous chains of cells which disarticulate and propagate the plant; these offshoots are known as chlamydospores or gemmæ.

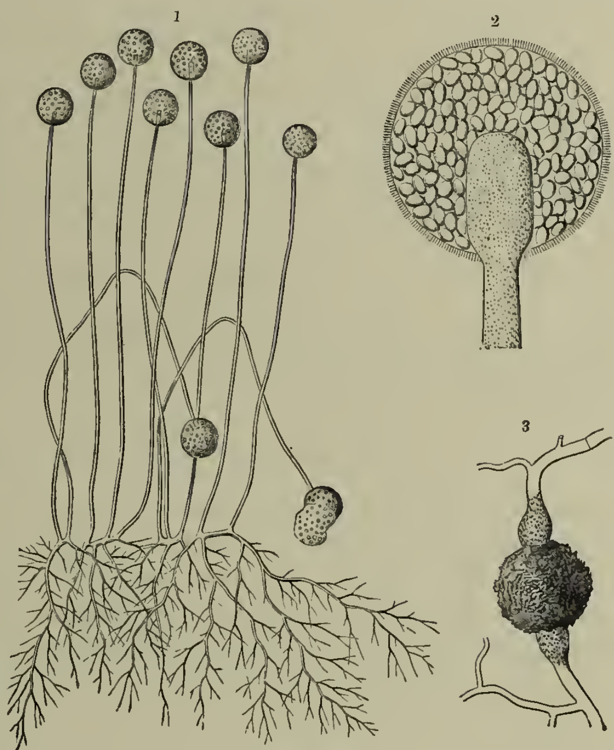


Fig. 384.—*Mucor.*
[1] Mycelium with stalked sporangia; ×40. [2] A single sporangium; ×260. [3] A zygospore produced by conjugation; ×160.

It often happens amongst the Mucors that although the conjugating branches are produced, they do not conjugate but each produces a fruit parthenogenetically. These, in contradistinction to zygospores, are called "azygospores". Or, as in *Mucor tenuis*, the "conjugating branches" no longer arise in pairs but isolated; these also form azygospores. Thus in this group, as in the Saprolegniaceæ of the alliance Oomycetes, we note a tendency for sexuality to become obsolete (*cf.* p. 670). A good deal of variety exists in the Mucoraceæ in the arrangement of the sporangia. In *Thamnidium* the sporangial branch ends in a large sporangium, and in addition bears laterally a number of tiny sporangia (sporangioles) containing four spores each, whilst in *Chœtocladium* there is a further reduction, and the sporangioles contain

but a single spore. Whilst the bulk of Mucoraceæ are saprophytes on animal excreta, &c., a certain number are parasitic on Mucor itself as well as other Fungi.

The *Mortierelleæ*, though in general resembling Mucoraceæ, are distinguished by the fact that their zygospores become invested in a plexus of mycelial hyphæ which form a sort of pericarp around the fruit. The base of the sporangial hypha also is invested in a sort of bird's-nest. This condition is of interest as it leads on to the more complex fruits of higher Fungi.

The Zygomycetes include 125 species.

Sub-Class II.—Mesomycetes.

Mycelium multicellular; asexual reproduction alone is known by means of spores (not limited in number) developed in sporangia; or by conidia. They are regarded as occupying an intermediate position between the lower Fungi and the two large groups of higher Fungi, the Ascomycetes and Basidiomycetes respectively.

Alliance XVI.—**Hemiasci.**

Tube-like sporangia containing an unlimited number of spores. This alliance leads on to the Ascomycetes.

Families: *Ascoideæ, Protomycetes, Theleboleæ.*

These are mostly simple forms of parasites characterized by the indefinite number of spores contained in their sporangia. Some of them produce chlamydospores freely. *Thelebolus* is interesting in that its sporangium is inclosed in a cortex and may be compared with *Mortierella* of the Zygomycetes on the one hand, and with the corticated Ascomycetes (carpo-asci) on the other.

There are about 20 species belonging to this alliance.

Alliance XVII.—**Hemibasidii.**

Parasites with a septate mycelium, which forms numerous chlamydospores. From these spores a promycelium is developed on which conidia (sporidia) are produced. No sporangia are formed. This alliance is thought to lead on to the Basidiomycetes.

Families: *Ustilaginaceæ, Tilletiaceæ.*

These are all parasitic forms, and are known as the Smuts. The mycelium grows in the living tissues of the host, and concludes its development with the production of chains of chlamydospores (cf. p. 673), which are provided with a thick membrane, and are usually dark in colour. It is in respect of this character that the name "Smut" has been given. Very often these chlamydospores are produced in connection with the fruiting organs of the host-plant (various Grasses, &c.). The

chlamydospores only germinate after they have been distributed, and in a very characteristic manner. A short tube is formed, and from this (the promycelium or *basidium*, *cf.* p. 674) conidia (= sporidia) are abstricted. In the Ustilaginaceæ this basidium is septate and the conidia are abstricted *laterally*; in the Tilletiaceæ the basidium is non-septate, and the conidia are abstricted as a crown at the apex. This is the main difference between the two families. The conidia, which are budded off from the promycelium, have the power of budding in a suitable soil with enormous facility, forming new conidia, and this may be continued for a considerable time. In this way the soil becomes thoroughly infected, and should a young seedling host-plant arise, it is almost certain to be penetrated and invaded by one of these germ-like conidia.

Ustilaginaceæ.—These are the Smut-fungi properly speaking. *Ustilago segetum* (= *Ustilago carbo*), the common Smut of Wheat, Barley, Oats, &c., has been very fully investigated. The cereals in question become infected when quite young by the tiny conidia, which put out delicate germinal tubes and penetrate the young growing tissues. Should the young plants escape infection at this stage, they are safe against the parasite, which cannot penetrate the hard, adult tissues. The tubules of the *Ustilago* penetrate from cell to cell, and take up their position at the growing point. Here they keep pace with the growth of the host, but the presence of the parasite is not manifest externally until the grain begins to ripen. As the grains begin to swell, the fungus increases rapidly, and occupies the greater portion of their substance with its mycelium. It thrives, of course, at the expense of the food which would otherwise have served in forming the embryo and reserve of food-material in the seed. Finally, the Fungus resolves itself into masses of black chlamydospores—the "smut"—which appear between the glumes of the ear. These chlamydospores, as already stated, after a period of rest, produce their promycelia and bud off conidia, which in turn bud off other conidia, and so the ground is kept infected. It was formerly a matter of mystery how the Fungus got into the host-plant, as traces of it were not recognized till it burst out in the ripening ear in the "smut" stage. It is only comparatively recently that the period of infection has been recognized, and the fact that the mycelium grew up, so to speak, with the host-plants was fully realized. *Ustilago Maydis* produces hypertrophied growths on the Maize, and has been alluded to in a former chapter (cf. p. 524). *Ustilago violacea* attacks the stamens of many Caryophyllaceæ, developing its chlamydospores in place of pollen in the anthers. *Ustilago longissima* is very common in the leaves of the aquatic Grasses *Glyceria aquatica* and *G. fluitans*; it produces its chlamydospores as long, parallel, black lines.

More than 60 Ustilagos have been distinguished; a large number of them attack cereals and other grasses.

Tilletiaceæ.—Have on the whole a life-history resembling the Ustilagineæ; their main point of difference residing in the fact that the promycelium is unsegmented, and produces its conidia in a crown at the apex. *Tilletia Tritici* attacks wheat. In *Urocystis* the spores are clustered into little balls, the accessory spores forming a

sort of cortex around the central spore which germinates as in *Tilletia*. *Urocystis Violæ* is common on the leaf-stalks and blades of Violets.

About 100 species of Tilletiaceæ have been distinguished.

Sub-class III.—Mycomycetes.

Mycelium many-celled. Reproduction asexual, either by spores of limited number in asci, or by conidia of limited number on basidia.

Alliance XVIII.—Ascomycetes.

Parasitic (or saprophytic) Fungi, producing spores in special tubular sporangia, the *asci*. These spores, termed *ascospores*, do not exceed 8 in number. In addition to the asci there are subordinate conidial fructifications.

Families: *Exoascaceæ, Perisporiaceæ, Pyrenomycetes, Discomycetes.*

As stated, this alliance is characterized by the possession of sporangial fructifications, consisting of tubular asci containing as a rule 8 ascospores. A number of such asci are shown in fig. 388 [2] with sterile supporting hyphæ, the paraphyses, between them. In addition to these ordinary and typical ascus-bearing fructifications, secondary fructifications producing conidia or chlamydospores are largely met with; consequently many of these Fungi appear under several forms in addition to the ascus stage. The Ascomycetes are divided into families according to the characters of the ascus-fruit. In the *Exoascaceæ* the asci are borne freely and exposed on the mycelium; in the other three families in special receptacles. In the *Perisporiaceæ* the group of asci is contained in a nut-like or tuber-like body; in the *Pyrenomycetes* the asci are produced in special pear-shaped excavations in a solid tissue which open by a pore to the exterior; in the *Discomycetes* the receptacle forms an open plate or cup, or sometimes an irregular body covered with the layer of asci.

Exoascaceæ.—This family comprises the parasitic genera *Exoascus* and *Taphrina*, the gall-like deformations caused by which were so fully described on pp. 524 and 527. The tissues of the host-plants are penetrated by the mycelia of these forms, and the asci are produced over the surface of the parts attacked, generally bursting through the cuticle of the epidermis. Each ascus contains 8 spores, but in many species many more than this number are often found; this is due to the fact that the 8 original ascospores begin to bud whilst still within the ascus, producing a large number of secondary spores (conidia). *Exoascus* has a perennial mycelium, and to its species are due a large number of the "witches'-brooms" and other hypertrophies. *E. Pruni* produces the "pocket-plum" (*cf.* p. 524); *E. Alni-incanæ* the curiously altered Alder catkins represented in fig. 358 [1] (p. 523); *E. Carpini* the birds'-nest-like witches'-brooms of the Hornbeam; *E. deformans* the "curl" of Peach-leaves. *Taphrina* is largely a leaf-parasite, and its mycelium is not perennial. *T. carnea* causes blisters on the leaves of the Birch.

About 50 species of Exoascaceæ have been distinguished.

Perisporiaceæ.—Here are included all forms in which the asci are inclosed in fruit-like bodies, *i.e.* the Mildews, Moulds, and Truffles.

The Mildews are chiefly leaf-parasites, and spread their mycelium over the surface of the foliage and send their suckers (or haustoria) into the epidermal cells (*cf.* fig. 32 [2], vol. i. p. 165). In due time they produce their ripe ascus-fruits like tiny black grains scattered over the surface of the leaf. Each of these fruits consists of a shell-like investment inclosing one or more asci, each of which contains 8 spores. *Sphærotheca* is the simplest form, there being but a single ascus in its fruit. *S. pannosa* is the Rose-mildew, and *S. Castagnei* the Hop-mildew, a very destructive parasite in Hop-growing districts. *Erysiphe* has several asci in its fruits, and includes the well-known *E. Tuckeri*, the true Mildew of the Vine (to be distinguished from *Peronospora viticola*, figured on p. 670, which is the false Mildew). A tropical genus of leaf-parasites allied to our Mildews is *Meliola*, which is widely distributed.

The Moulds include several exceedingly common saprophytes which make their appearance on the most various sorts of organic matter. The Blue Moulds, which occur on jam, bread, leather, &c., are probably the best known and most commonly recognized of all the smaller Fungi. These forms spread their mycelia over any suitable substratum, and penetrate it with their hyphæ. Their usual fructification is not the ascus-fruit, but clusters of conidia, borne on erect hyphæ, which stand out from the mycelium. Two common Moulds are represented in fig. 193, p. 18. *Aspergillus niger* (figs. 193 [4] and 193 [5]) bears its conidia in spherical tufts on enlarged aërial hyphæ. The swollen end of an aërial hypha is densely set with cylindrical cells, from which the conidia are abstricted one after another. *Penicillium crustaceum* (figs. 193 [8] and 193 [9]) is very similar, but here the conidia are borne on a hypha which branches near its extremity like a compound umbel. Another form, *Eurotium*, is shown in fig. 385 [7], p. 679. The ascus-fruits of these Moulds are not very conspicuous, nor are they always very plentifully developed. They arise on the mycelium after the conidial stage is over, and when ripe are about the size of small shot. They commence by the entwining of certain hyphal branches (*Penicillium*, fig. 193 [6], p. 18; *Eurotium*, fig. 385 [9], p. 679) which have been regarded as representing male and female organs (*cf.* p. 60). That fertilization takes place is strenuously denied by many modern mycologists, and the sexual nature of the entwining hyphæ is not universally recognized. Be this as it may, the result of the process in question (which also takes place in the Mildews) is the formation of a sinuous hypha, which becomes embedded in a dense cortical sheath which grows up from the mycelium close by the place of origin of the entwined hyphæ. This is the young fruit-body; that of *Eurotium* is shown in section in fig. 385 [10]. From the central hypha numerous asci, each containing 8 spores, are ultimately developed (figs. 193 [7] and 385 [11]). The ripe ascus-fruit, which frequently takes several months to mature, consists of a hard outer shell containing numerous asci (one of these fruits is shown in fig. 385 [7], in the right-hand bottom corner); it is

able to remain dormant over long periods. *Aspergillus* is sometimes parasitic, and is stated to promote a diseased condition of animal tissues known as *mycosis*. *A. fumigatus* is found growing spontaneously in the air-passages of birds and in the human lungs.

Tuberaceæ.—These are subterranean saprophytes whose mycelia grow in humus. Their fructifications are solid, tuber-like bodies of various sizes. The Truffles (*Tuber rufum, T. melanosporum, T. æstivum,* &c.) are well-known, and several of the species are esteemed as delicacies. In section the Truffle-fruit shows a curious mottled appearance due to its irregular chambered character. The chambers are filled with hyphæ which produce numerous oval asci, each containing 4 spores (*cf.* fig. 387 [1], which represents an enlarged chamber); the spores are covered with delicate spines. The wall of the fructification consists of a hard parenchyma-like layer, and possesses a rough and warted exterior. As the fructification ripens the mycelium disappears, the Truffles being found detached in the soil. The spores are ultimately liberated by the decay of the fruit. *Elaphomyces* produces fruits about the size of a nut. The mycelium of species of this genus is concerned in the formation of the fungal investment or mantle of the roots of Pine-trees known as mycorhiza (*cf.* vol. i. pp. 249, 250); in the Amentaceæ, &c., neither the species nor group to which the Fungi forming this mantle belong has been ascertained.

Pyrenomycetes.—An extremely large and varied group, including both parasitic and saprophytic forms. The essential character of the family is the presence of flask-shaped chambers with a pore at the apex in which the asci are produced. The chambers, the *perithecia,* may be either solitary upon the mycelium in the simpler forms or embedded in receptacles of most varied form (the stromata) in the more complex. Sections of perithecia are shown in figs. 385 [5] and 386 [5]. A great many Pyrenomycetes possess conidial as well as ascus-fructifications. The conidia may arise in tufts from the surface of the mycelium or in urn-shaped cavities—not unlike perithecia—which have been termed *pycnidia.* As a rule, the conidial precedes the ascal stage. This variety in fruiting has led to the recognition of several forms, which are only stages in the life-history of one Fungus. Consequently, as knowledge extends, many of these supposed species have to be suppressed.

Among the simpler forms may be mentioned *Podospora,* which produces solitary sessile perithecia upon its mycelium. *Polystigma rubrum,* which occurs on the leaves of species of Cherry and Plum, produces a brilliant red spotting on the leaves. The mycelium permeates the internal tissues, and during the summer the conidial receptacles or pycnidia are formed. Later, usually in the following spring, in the fallen leaves, the perithecia arise, and the ascospores now liberated infect the young foliage in the vicinity. *Nectria cinnabarina,* another fairly simple form, occurs as little red cushions on the branches of Horse-Chestnut, Elm, Sycamore, &c.; these cushions burst through the bark budding off conidia (this is the bright red stage), whilst later, as tiny lobes, the perithecia arise upon them, each lobe containing a single perithecium (this is the dull crimson stage). The number of simple parasitic Pyrenomycetes is almost endless.

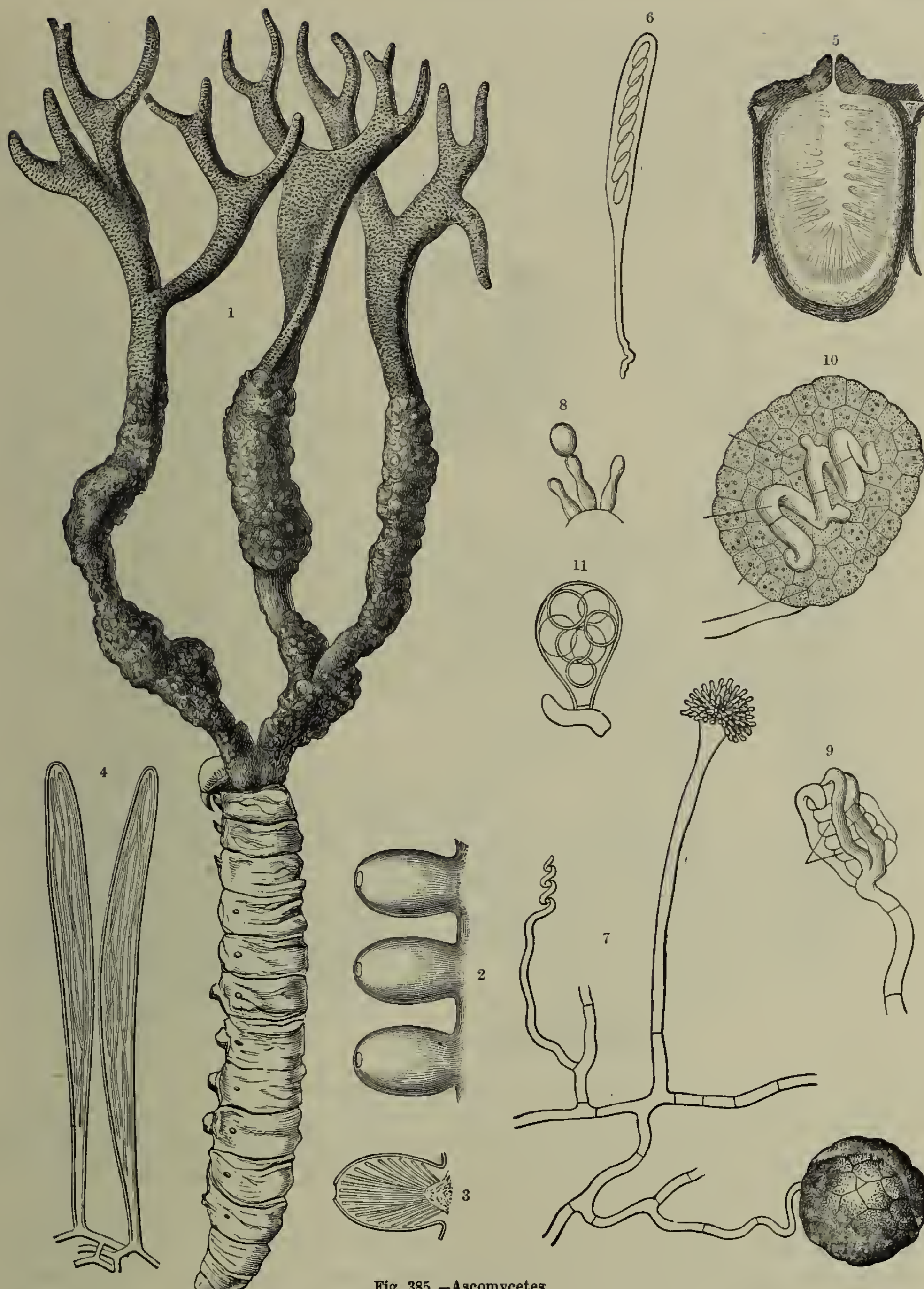


Fig. 385.—Ascomycetes.

[1] *Cordyceps Taylori*, a pyrenomycetous Fungu which attacks caterpillars; the branched antler-like stroma has developed from the sclerotium, and its lower warted portion bears the perithecia. [2] Three perithecia; enlarged. [3] A perithecium in section. [4] Two asci containing filamentous spores. [5] Vertical section of a perithecium of *Xylaria Hypoxylon*. [6] Ascus of same. [7] Mycelium of *Eurotium* bearing a conidial hypha (to right, above), a commencing fruit (to left), and a ripe ascus-fruit (to right, below). [8] A conidium of the same being abstricted. [9] Entangled hyphæ from which a fruit arises; the spiral central hypha has been interpreted as a female organ, the tubes growing up the side as male. [10] A young fruit of the same in section; the asci arise later from the large coiled central hypha. [11] A single ascus of *Eurotium*. [1] nat. size; [2], [3], [5] $\times$ 50–90. [4], [6] $\times$ 500; [7] $\times$ 190: [8–11] $\times$ 250.

Of complex forms with stromata we may mention *Cordyceps*, *Xylaria*, and *Claviceps*. *Cordyceps militaris* and other species attack caterpillars. The germ-tube having once effected an entrance into the body of the caterpillar and established itself in the superficial layers begins to sprout vigorously, these sprouts being carried in the blood to all parts of the body. The sprouts now grow into hyphæ, and gradually the whole caterpillar is replaced by a dense fungal tissue which

Fig. 386.—The Ergot of Rye, *Claviceps purpurea*.

1 Ear of Rye showing two sclerotia of the Fungus. 2 Conidia arising from the mycelium which develops around the ovary. 3 Stalked stromata arising from the sclerotium. 4 Longitudinal section through the head of a stroma showing the perithecia at the edge. 5 Vertical section through two perithecia showing the asci. 6 Asci. 7 Ascus liberating its filamentous spores. 8 Filamentous spores. 1, 3 nat. size; 2×200; 4×40; 5×50; 6 and 7×700; 8×750. (Partly after Tulasne.)

maintains outwardly the form and appearance of the caterpillar, although of animal substance but little traces are left. This fungal mass is known as a *sclerotium*, and it can remain dormant for some time. Ultimately a branching stroma arises from the sclerotium (*Cordyceps Taylori*, fig. 385 1, p. 679), or, in *C. militaris*, several club-shaped stromata. These remarkable stromata are covered with little papillæ on their lower portion, and each of these papillæ corresponds to a perithecium (figs. 385 2 and 385 3). The spores in the asci are long and slender (*cf.* fig. 385 4). A

Pyrenomycete which produces an antler-like stroma resembling that of *Cordyceps Taylori,* and which is exceedingly common on old tree stumps, is *Xylaria Hypoxylon.* Indeed, the stroma represented in fig. 385 [1] would almost do for that of this *Xylaria.* It is purplish in colour below where the perithecia are borne; at the tips it passes over into a glaucous grey colour, this bloom being due to the conidia, which are abstricted in this region. Another curious fingered species, *X. polymorpha,* is also met with in similar situations. *Claviceps purpurea,* the Ergot

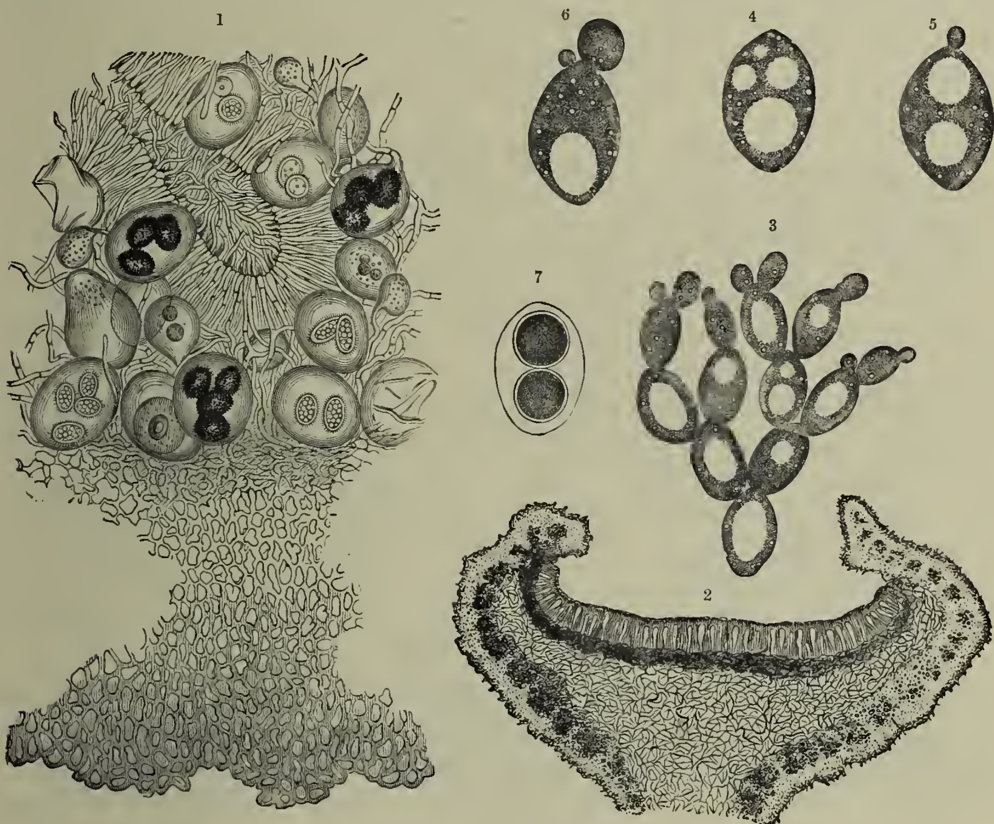


Fig. 387.—Various Ascomycetes.

1 Section through part of a Truffle (*Tuber melanosporum*) showing a portion of the cortex (below) and a chamber containing oval asci, each of which contains 4 spores. 2 Vertical section of the apothecium of a discomycetous Lichen, *Physcia ciliaris* (after Sachs). 3 The Yeast-plant, *Saccharomyces cerevisece.* 4, 5, 6 Single Yeast-cells showing development of a sprout. 7 A cell containing two spores. $^1\times 200$; $^2\times 60$; $^3\times 600$; $^{4-7}\times 1000$. (Partly after Rees.)

of Rye and other grasses, is a very interesting form. The spores attack the ovaries of Grasses and invest them with a mycelium from which conidia are abstricted in large numbers (fig. 386 [2]). These can at once infect new plants. Gradually the whole ovary is replaced by a mass of fungal substance, the sclerotium. In the autumn at the time of harvest the ears of Rye may be seen with these dark sclerotia projecting from them (fig. 386 [1]). Care has to be exercised that they do not get mixed up with the grain, as the Ergot contains an alkaloid and other poisonous substances, and if intermingled with food causes a disease which has received the name of ergotism. The sclerotia remain dormant through the winter,

but in the spring give rise to their stromata, which consist of a number of orange-coloured spherical bodies borne on purple stalks. A germinated sclerotium is shown in fig. 386 [3]. The head bears the perithecia at its periphery (figs. 386 [4] and 386 [5]), and in these are contained the asci with their filamentous spores (figs. 386 [6, 7, 8]).

In addition to the forms enumerated above, a large number of pyrenomycetous Fungi are found always associated with Algæ into symbiotic communities known as *Lichens* (*cf.* vol. i. p. 244). Though in a strict systematic review these forms should be noted here, still, as Fungi from at least two other groups occur in similar relations to Algæ, it will be convenient to treat them all under one heading, rather than scattered over the alliances with which they have a natural affinity (see *Lichenes*, p. 691).

Discomycetes.—These, like the Pyrenomycetes, constitute a very extensive family. They are characterized by the fact that when mature the structure bearing the asci expands into a disc or cup, so that the ascal surface is exposed; or this surface is spread over the outside of a fleshy receptacle.

As a good example of a Discomycete, the large genus *Peziza* may be cited. They are met with chiefly on decaying vegetable matter, and in the various species the disc or cup—the fertile receptacle—is sessile on the mycelium. *Peziza vesiculosa* (*cf.* fig. 388 [5]) is one of the commonest British species, occurring in humus, rotting leaves, &c. Its cups (the apothecia) attain a diameter of 2–3 inches, are buff in colour, fleshy, and very fragile. The inside of the receptacle is everywhere lined with the layer of asci, with sterile hairs, the paraphyses, between (it is similar to fig. 388 [2]). Another common species is *P. scutellata*; it forms little flat red discs about the size of sixpenny-pieces upon rotting wood, and the margin is set with hairs. Several of the Pezizas are stalked (*cf.* figs. 388 [3] and 388 [4]). *P. æruginosa* is an interesting form; it also is stalked, and grows especially upon dead branches of Oak. It permeates the wood with its mycelium, and this appears to excrete a green pigment which stains the wood in its vicinity. The stalked apothecium is also green in colour. This green-rotting wood is exceedingly common and is used in the manufacture of "Tunbridge ware"; the actual Fungus, however, is by no means so obvious, and from the majority of green-rotted branches not only has the apothecium disappeared, but the mycelium also. Resembling a *Peziza*, but very gelatinous, is *Bulgaria inquinans*, common on decaying trunks of trees. *Peziza Willkommii*, causing the Larch-canker, has been already referred to (*cf.* p. 522). Nearly related to the Pezizas, and causing parasitic diseases of plants, is *Sclerotinia*. It possesses a well-marked sclerotium, from which stalked Peziza-like apothecia are produced. A species not uncommon in this country is *Sclerotinia tuberosa*. It attacks the underground parts of Wood Anemones and forms its sclerotia in the tubers of this plant. In the spring, instead of Anemone-flowers coming up, the sclerotium gives rise to a number of long-stalked apothecia which appear just above the surface of the ground.

Other more complex Discomycetes are the Helvellas and Morels, forms purely saprophytic. *Helvella* produces a stalked receptacle, curiously folded (see figs. 388 [6]

and 388[7]) and plaited; the whole of the exposed surface of this receptacle is covered with asci. The Morel (*Morchella esculenta*, fig. 388[1]) possesses a thick stalk bearing a large fleshy receptacle marked out in pitted areas. Nearly allied is the genus *Geoglossum*, possessing club-shaped receptacles, black in colour, and covered with asci. *G. difforme*, 2–4 inches high, is often met with among grass in the autumn.

The *Lichenes* belonging to this family are treated with the other Lichens at p. 691.

Reference to a small group of forms, the *Saccharomycetes* or Yeasts, may be

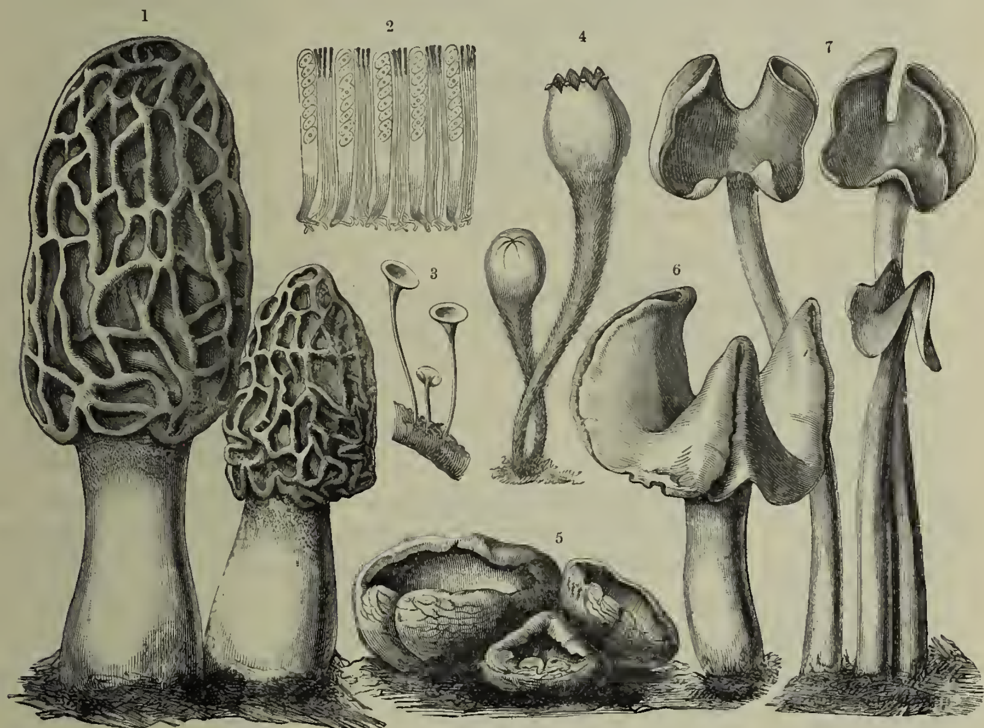


Fig. 388.—Discomycetes.

[1] The Morel (*Morchella esculenta*). [2] Vertical section of the fertile surface of the Morel showing five asci with their spores and filamentous paraphyses between the asci. [3] *Peziza* (*Helotium*) *Tuba*. [4] *Anthopeziza Winteri*. [5] *Peziza vesiculosa*. [6] *Helvella infula*. [7] *Helvella fistulosa*. [1, 4, 5, 6, 7] nat. size; $^3\times 4$; $^2\times 120$.

introduced here. They constitute a detached family with ascomycetous affinities, and characterized by their very peculiar mode of life. For the most part they do not form mycelia, but increase by budding and by the formation of spores. *Saccharomyces cereviseæ* is the well-known Brewer's Yeast. The cells are oval and colourless, and provided with one or more conspicuous vacuoles; the cell-nucleus is not readily demonstrable, though there is little doubt of its existence. Growth here is by budding, little processes being pushed out at the periphery at one or more spots and gradually enlarging (figs. 387[4, 5, 6]); ultimately they are cut off from the parent-cell by the completion of the membrane across the point of union. In this

way groups of cells may hang together in chains (fig. 387[3]) for a short time, but they disarticulate sooner or later. As the substratum becomes exhausted the cells exhibit a tendency to form spores in their interior (2–8), the cell being as it were transformed into an ascus (fig. 387[7]). The special physiological activity associated with this and several other species is alcoholic fermentation (*cf.* vol. i. p. 506), *i.e.* the splitting up of sugar into alcohol and carbonic acid. *S. cereviseæ* is used in brewing, *S. ellipsoideus* causes the fermentation in the juice of the Grape. *S. mycoderma* forms a scum on wine and beer, and is of interest in that it produces mycelial tubes.

In all there are some 40 species of *Saccharomyces.*

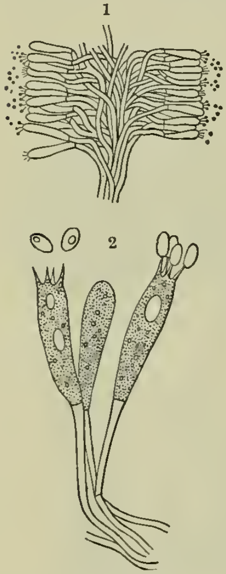


Fig. 389.

1 Portion of a lamella of an *Agaricus* with a basidial layer (from which conidia are being budded off) on either side. 2 Shows three basidia, more highly magnified, from the basidial layer of the same fungus; conidia are being abstricted from the four processes (sterigmata). $^1\times200$; $^2\times500$.

Alliance XIX.—**Basidiomycetes.**

Parasites and saprophytes, reproducing by means of conidia which arise on basidia in definite number. Besides these characteristic conidia there are subordinate fructifications.

Families: *Uredineæ, Auriculariaceæ, Tremellaceæ, Pilacraceæ, Dacromycetes, Hymenomycetes, Gasteromycetes.*

The Basidiomycetes are an exceedingly large alliance, and include forms from the simplest to the most complex. They all agree, however, in the production of conidia from a definite *basidium*, a character which gives its name to the group. As has been already pointed out (p. 674) there are two families in the Hemibasidii, *i.e.* the Ustilaginaceæ and the Tilletiaceæ. In both families a promycelium or basidium arises from the chlamydospore; in the former it is septate and conidia are cut off laterally, in the latter it is non-septate and the conidia are produced in a tuft at the extremity. In the Uredineæ a basidium arises from each cell of the teleutospore (the probable equivalent of a chlamydospore), and this basidium is transversely septate, four cells being cut off at the end of the tube away from the spore. Each of these cells produces a little process, and from each process a conidium is abstricted. In all the other families of Basidiomycetes the teleutospore (or chlamydospore) is suppressed, and the basidia are directly continuous with the hyphæ of the Fungus. Otherwise, the basidia of Auriculariaceæ, Tremellaceæ, and Pilacraceæ, all belong to the type of the Uredineæ, and are derivable from the *Ustilago*-form. On the other hand, the basidia of Hymenomycetes and Gasteromycetes, and probably also of Dacromycetes, belong to the *Tilletia* type (*cf.* p. 675). The conidia do not arise laterally, but from four processes at the tip of an unsegmented basidium (see figs. 389[2] and 390[7]). The very general restriction of the number of processes arising on the basidium to four is without doubt a feature of some importance, and

is a further justification for the inclusion of all these families—at first sight so different—in a single alliance.

Uredineæ.—These are the Rust-fungi, parasites for the most part on the foliage of higher plants. They are outwardly manifest in the form of yellow or brown

Fig. 390.—Basidiomycetes.

[1] *Clavaria aurea.* [2] *Dædalia quercina.* [3] *Marasmius tenerrimus.* [4] *Marasmius perforans.* [5] *Craterellus clavatus.* [6] *Amanita phalloides.* [7] A portion of the basidial layer of the last-named Fungus showing the sterigmata and conidia. [8] *Hydnum imbricatum.* [9] *Polyporus perennis.* [7] ×250; the rest nat. size.

spots and streaks, due to the spores, which are formed in masses on the surface. The mycelium inhabits the intercellular system of the host-plant, and draws its nourishment from the living cells. The spores are regarded as chlamydospores, that is to say, localized, thick-walled segments of the hyphæ having the properties of reproductive cells. These spores are met with in three forms in the Uredineæ. The

Teleutospores (from τελευτή, an end), which are the type most universally present, arise towards the end of the vegetative period. In the majority of cases they remain dormant during the winter. On germinating they form a 4-celled basidium, from each cell of which a conidium is abstricted. Commonly the teleutospores are in rows of two, *i.e.* constitute spindle-shaped, 2-celled bodies, each cell (spore) of which can produce a basidium. Sometimes the teleutospores are in many-celled rows, occasionally solitary. The *Uredospores* (from *uro*, to burn) as a rule precede the teleutospores and germinate at once. They are oval and unicellular. The *Æcidiospores* arise in chains in special receptacles (the æcidium-fruits) which are at first closed. Both uredospores and æcidiospores differ from teleutospores in that they produce a mycelium at once on germination. They never form basidia and conidia. A fourth sort of reproductive organ, a secondary conidial stage, is often found associated with the æcidium stage; this is the pycnidium (*cf.* p. 678), a hollow receptacle whose lining cells abstract tiny condia. The fate of these pycno-conidia and the part they play in the life-history of the Fungus is unknown.

There is thus in the Uredineæ great variety in the kinds of reproductive cells. Some species possess all of them and produce them one after another upon the same host-plant (e.g. *Puccinia galii* and *P. primulæ*); others possess teleutospores only or teleutospores and one of the other types, whilst in others again all the forms are present, but they are not developed upon the same host-plant. This latter property of developing the different stages on two host-plants (known as *heterœcism*) is by no means uncommon amongst the Uredineæ. It is remarkable enough to merit a short description here, though, of course, any exhaustive account of the family as a whole is impossible. The following are well-known cases of heterœcism. *Coleosporium senecionis*, which produces its uredospores and teleutospores on the Groundsel (*Senecio vulgaris*), its æcidiospores on *Pinus sylvestris* (the latter stage formerly known as *Peridermium pini*); *Puccinia graminis*, which produces its uredospores and teleutospores on Wheat and other grasses, its æcidiospores on the Barberry (this stage formerly known as *Æcidium berberidis*); *Gymnosporangium juniperinum*, which produces its teleutospores on the Juniper, its æcidiospores on the Mountain Ash (*Pyrus aucuparia*). These three may serve as types of a very large number of similar forms. *Puccinia graminis*, the Rust of Wheat, is the most famous of all. The æcidium-stage (accompanied by pycnidia) arises in spring on the foliage of the Barberry and the æcidiospores here produced cannot germinate on the same host, but only on Wheat, Oats, Rye, or some other Grass. Here a new mycelium is established bearing first uredospores and later on teleutospores. The uredospores can germinate at once on other grasses, but the teleutospores remain dormant through the winter, and in spring give rise to basidia from which conidia are abstricted; these conidia can germinate only on the Barberry—not on grasses—and from the mycelium which arises from them fresh æcidium-fruits are developed. In the absence of either host-plant (*i.e.* of the Barberry or of suitable Grasses) the life cycle of the *Puccinia* is of course interrupted. For the extermination of the Rust disease of cereals the removal of Barberry bushes is an obvious measure. In

parts of Europe, however (*e.g.* many upland valleys in Switzerland) this precaution is not taken and the *Æcidium*-covered Barberries and rusted crops may be seen standing side by side. It is true the rust does not destroy the wheat crop entirely but it seriously diminishes the yield of grain. Long before the life-history of the Rust-fungus had been scientifically traced the Barberry was known to have an evil influence upon cereals. So long ago as 1760 the state legislature of Massachusetts passed an Act[1] compelling the inhabitants to extirpate all Barberry bushes. The main facts connected with the life-history of *Gymnosporangium* have already been mentioned (*cf.* p. 522), and the two stages are represented on p. 521. The projecting lobes on the Juniper (fig. 357 [1], page 521) consist of masses of teleutospores embedded in mucilage. When wetted they swell up, the basidia are produced and the conidia abstricted; the latter are then blown away and, should they alight upon the young foliage of a suitable member of the Pomaceæ, penetrate the tissues and produce the *Æcidium* stage. The effects of various other members of this group are referred to on pp. 524, 525. Between four and five hundred parasitic Uredineæ have been distinguished.

Auriculariaceæ. — Include the well-known Jew's-ear Fungus (*Auricularia sambucina*) not infrequent on dead branches of the Elder. From its fertile surface basidia with conidia resembling those of the last family are produced, but the basidia are continuous with the hyphæ of the Fungus, no chlamydospores being produced

Tremellaceæ.—Gelatinous forms found on rotting tree-trunks. Their substance is curiously lobed and plaited; *Tremella Mesenterica,* which forms large gelatinous orange masses on dead branches, is the commonest of them.

Pilacraceæ.—Include a single genus only, *Pilacre*; it grows on Beech-bark, and consists of a spherical head mounted on a stalk. It is of interest because its basidia (from which the conidia are abstricted) are inclosed in a loose layer of hyphæ—the outward continuations of the hyphæ upon which the basidia are borne—and it is thought to lead on the family of the Gasteromycetes, in which the basidia are entirely covered in.

Dacromycetes.—Gelatinous forms resembling the Tremellaceæ. They approach the Hymenomycetes in that their basidia are destitute of septa. The processes from which the conidia are abstricted are very long. *Dacromyces deliquescens* is common as a red-coloured tough gelatinous mass on wooden palings.

Hymenomycetes.—An extensive family characterized by the production of a

[1] THE BARBERRY LAW OF MASSACHUSETTS.—Anno Regni Regis Georgii II. Vicesimo Octavo, Chap. X. (published January 13, 1755).

An Act to prevent Damage to English Grain arising from Barberry Bushes.

Whereas it has been found by experience, that the Blasting of Wheat and other English grain is often occasioned by Barberry Bushes, to the great loss and damage of the inhabitants of the Province:—

Be it therefore enacted by the Governour, Council, and House of Representatives, that whoever, whether community or private person, hath any Barberry Bushes standing or growing in his or their Land, within any of the Towns in this Province, he or they shall cause the same to be extirpated or destroyed on or before the thirteenth Day of June, Anno Domini One Thousand Seven Hundred and Sixty. And so forth. (From Plowright's *British Uredineæ.*)

fertile surface (the *hymenium*) consisting of basidia with 4 processes (or *sterigmata*) from each of which a conidium (or *basidiospore*) is abstricted. Typical basidia are represented in fig. 389 [2], p. 684, and fig. 390 [5]. The hymenium in this group is exposed at the time when the basidiospores are produced.

As in the Ascomycetes, so here, there is an extensive range of forms from simple to complex. Simplest of all are the *Exobasideæ*, mostly parasites on Ericaceæ. *Exobasidium Rhododendri*, which causes the Alpine Rose apples, has already been mentioned (p. 520), as also *E. Vaccinii* and *E. Lauri* (p. 526). The hymenium in these simple forms is produced over the whole surface of the hypertrophy or blister caused by the Fungus. In the *Telephoreæ* a definite tissue bearing the hymenium is developed; this is termed the hymenophore or fructification. In the simple *Corticium* this forms smooth sheets of waxy nature everywhere encrusting the substratum. The basidia occur over the free surface. *Stereum*, also very common on old trunks, forms leathery plates usually attached laterally or stalked. The hymenium is on the smooth under surface, whilst the upper surface of the fructification is more or less velvety. *Craterellus* (fig. 390 [7]), laterally attached, is hollowed out above; the under surface is the fertile one. In the *Clavariæ* the fructification is club-shaped and fleshy, and covered externally by the hymenium—as in the sulphur-yellow *Clavaria inæqualis* very common on grass lawns and pastures—or it is branched and coral-like as in *Clavaria aurea* (fig. 390 [1]). In the *Hydneæ* there is a well-marked distinction into a stalk and cap (known as the *pileus*); the hymenium is on the under surface, and is in the form of a number of crowded spines or teeth (e.g. *Hydnum imbricatum*, fig. 390 [8]). The *Polyporeæ* form a large and important group, characterized by the fact that the hymenium has the form of a number of pits, tubes, or meshes, usually on the under surface of the fructification. The simplest of these is the Dry-rot Fungus, *Merulius lacrymans*. The mycelium of this Fungus penetrates the substance of ill-preserved woodwork in houses, disintegrating it and reducing it to a brittle consistency. At places it produces fructifications, flat irregular bodies whose under surface, the hymenium, consists of a honeycombing of shallow depressions. The property which these fructifications possess of excreting drops of water has given to this Fungus the name *lacrymans*. In *Polyporus* the hymenium has the form of numerous fine tubes lined with basidia. The fructification may be either bracket-like, as in *Polyporus fomentarius* (growing on the Beech-trunk to the right hand of Plate XIV.), or it may have the cap-like form of a mushroom mounted on a central stalk, e.g. *P. perennis* (fig. 390 [9]) and the allied *Boletus edulis* (Pl. XIV. left-hand bottom corner). To these Polyporuses belong some of the most destructive diseases of timber, their myceliums penetrating the wood everywhere, softening and disintegrating it (e.g. *Polyporus igniarius*, *P. fomentarius*, *P. sulphureus*, and *P. annosus*—otherwise known as *Trametes radiciperda*). The last-named *P. annosus* causes a well-known disease of coniferous timber, the wood coming out in white spots before it is finally disintegrated. It is of interest because the fructifications are produced on the roots of the trees attacked. Allied to *Polyporus*

is *Dœdalia* (fig. 390 [2]) a bracket-like form in which the hymenium takes the form of irregular branching slits on the under surface. The *Agaricineæ,* which include the very numerous mushroom and toadstool Fungi, are for the most part umbrella-like in form, having a central stalk and expanded circular receptacle (the pileus). The under surface of the pileus is occupied by lamellæ or gills which radiate from the insertion of the stalk to the margin of the pileus (*cf.* figs. 390 [3, 4, 6]). The basidia forming the hymenium are set upon the sides of these gills. Fig. 389 [1] shows an enlarged section through a part of a gill. In the more complex forms certain structures are present inclosing the young fructification, but they are ruptured as the pileus expands, and in adult fructifications the gills are freely exposed. Their remains may often be seen on the mature Fungus, as in *Amanita* (fig. 390 [6]). Just below the pileus there is a membranous ring (the *annulus*); at an earlier period it was attached to the margin of the pileus covering in the hymenium, and forming what is termed the *velum partiale.* In the same Fungus may be noted the remains of another sheath, the *velum universale,* which enwrapped the entire fructification. This is shown in fig. 390 [6] as a ruptured sheath (the *volva*) at the base of the stalk, whilst portions of the covering which invested the pileus (and was continuous with the ruptured sheath alluded to) are to be seen as white felty patches on the scarlet pileus of *Amanita muscarius* (*cf.* Plate XIV.). The forms and varieties of the Agaricineæ are far too numerous even for mention. Many of them are edible, notably the Mushroom, *Agaricus campestris,* and the yellow-coloured *Cantharellus cibarius* (allied to the Agaricineæ, Plate XIV. on the left). Others again are poisonous, as, for instance, the scarlet *Amanita muscarius* (Plate XIV.), which receives the name *muscarius* from the fact that decoctions of this Fungus were formerly used for killing flies. Certain forms (*Russula* and *Lactarius*) contain a latex of a white or yellow colour. A number are characterized by producing sclerotium-like bodies (*cf.* p. 681). As a rule in the Agarics the fructifications arise directly from the mycelium, but in *Coprinus stercorarius, Lentinus,* &c., tuber-like masses of fungal substance are formed, and it is from these that the fructifications arise. These sclerotia, often attaining large dimensions, have been found by travellers in various parts of the world, and the fructification which arises from them is not in all cases known. Several of them, formerly name *Pachyma,* &c., are now known as belonging to the genus *Lentinus.* Very curious are the string-like sclerotia of *Agaricus melleus* which, from their root-like nature, were formerly termed "Rhizomorphs". They are found especially in Conifers, growing between the wood and bark, and having a ribbon-like form; from them cylindrical branches may arise which penetrate the soil and attack the root of some other tree. Ultimately the mushroom-like fructifications arise from these rhizomorphs.

A few lichens derived from the Hymenomycetes are treated at p. 695.

Gasteromycetes.—These are characterized by the fact that the basidia arise in closed chambers, which collectively constitute the *gleba,* and that this is covered by a continuous cortex or *peridium.* They include the Puff-balls, Earth-stars, Stink-

horns, &c. They are all of them more or less subterranean saprophytes, appearing above the surface to discharge their spores. The arrangements for the accomplishment of this purpose are very varied. The Puff-balls include the genera *Lycoperdon, Bovista, Scleroderma,* &c. When young a large portion of the interior has a chambered structure (the gleba), and in these chambers the spores are budded off. At maturity the fructification appears above the surface of the ground, and the whole of the substance of the walls of the chambers breaks down, except for certain branching threads (the *capillitium,* see fig. 391 [3]), which persists along with the

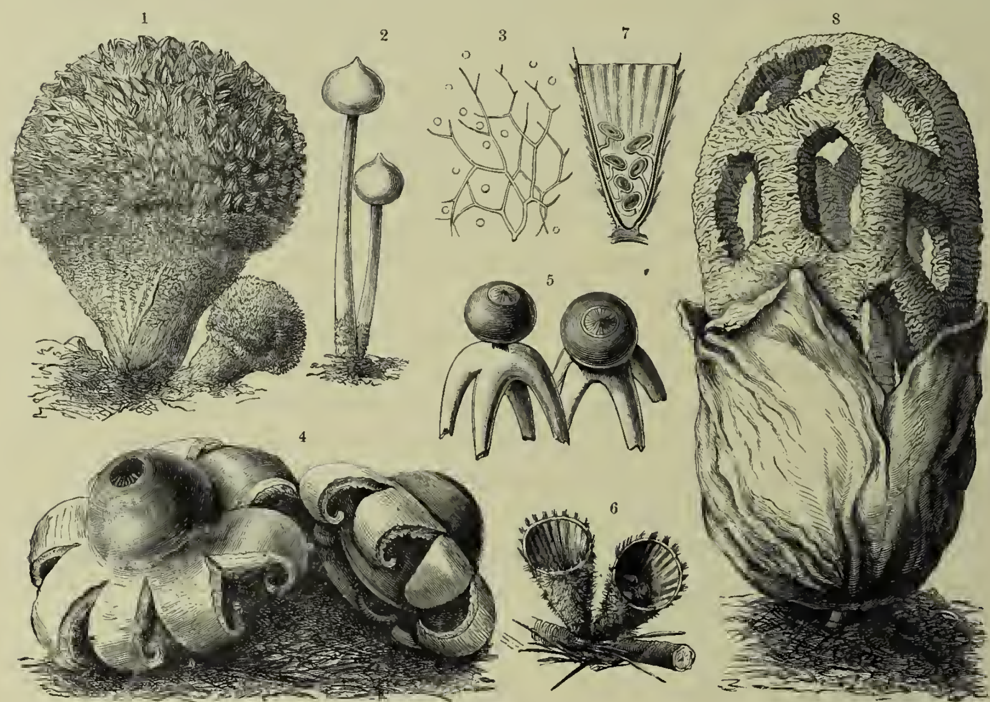


Fig. 391.—Gasteromycetes.

[1] *Lycoperdon constellatum.* [2] *Tulostoma mammosum.* [3] Capillitium and spores of *Tulostoma.* [4] *Geaster multifidus.* [5] *Geaster fornicatus.* [6] *Cyathus striatus.* [7] Longitudinal section of same. [8] *Clathrus cancellatus.* [3] $\times 80$; [7] slightly enlarged; the rest nat. size.

minute spores (*Scleroderma* has no capillitium). The latter escape by the peridium becoming perforated. *Lycoperdon* (see fig. 391 [1]) differs from *Bovista* in having a sterile basal portion, which is sometimes considerably elongated. In *Tulostoma* (fig. 391 [2]) the outer layer of the peridium bursts and the sterile basal portion elongates considerably, hoisting up the gleba inclosed in an inner peridium. The Giant Puff-ball (*Lycoperdon giganteum*) sometimes attains huge dimensions—occasionally a metre in diameter. Allied to the Puff-balls is *Geaster,* the Earth-star (figs. 391 [4] and 391 [5]). In this genus the outer peridium splits into segments and folds back, the inner peridium becoming perforated and liberating the spores. Earth-stars are met with now and then, but they are not usually very common. In *Cyathus* (figs. 391 [6] and 391 [7]) we have a form resembling a little bird's-nest

containing eggs. Here the chambers, instead of being numerous and deliquescent as in *Lycoperdon*, are few and provided with thick, hard walls; they arise in a matrix which occupies the whole body of the Fungus, and when mature they become isolated by the disappearance of the matrix. Each chamber is attached by a string to the wall of the peridium (*cf.* fig. 391 [7]). The opening at the top arises by the coming away of a membrane which previously closes it in. Perhaps the most remarkable group of Gasteromycetes is the *Phalloideæ*, which includes the common Stink-horn Fungus and other forms. Whilst immature they are egg-like, but at ripening the investment bursts and the remarkable gleba is hoisted up. *Clathrus* (shown in fig. 391 [8]) has its gleba spread over a hollow spherical lattice-work; the gleba is red in colour and the appearance of the Fungus very striking; it is rare in this country. The Stink-horn, *Phallus impudicus*, is less rare. When the gelatinous investment bursts, a spongy, spindle-shaped stalk expands and raises up the green, cap-like gleba. The Phalloideæ depend upon insects for the dispersal of their spores. Flies are attracted by the bright coloration and foul smell of these Fungi, and they lick up the mucilage into which the gleba deliquesces with great avidity. Perhaps the tropical *Dictyophora phalloidea* is the most remarkable of the group. It resembles a *Phallus*, but unfolds around itself a delicate white network which hangs expanded from below the gleba-cap like a crinoline. It is thought that this appendage—like the white corolla of a night-flowering plant—renders the Fungus additionally conspicuous after dark. The Phalloideæ, in reference to their marked attraction for insects, are sometimes spoken of as the "Flowering Fungi".

ADDITIONAL GROUP OF FUNGI.

LICHENES.

In our review of the various alliances and families of Fungi the fact has been from time to time noted that certain members of various groups live symbiotically with Algæ as Lichens. Though obviously all these Lichen-fungi do not constitute a natural group or alliance, we propose treating them for convenience together. The general characters of Lichens and their mode of life have been already indicated in the chapter commencing at vol. i. p. 243; consequently little but an enumeration of the groups of Lichens and their methods of reproduction is required now. Briefly, a Lichen consists of a Fungus and an Alga upon which the Fungus lives parasitically. But it is something more than a mere parasitic Fungus on a green plant. The mycelium involves the Alga in the most complete manner (*cf.* fig. 392), but it doesn't kill it like an ordinary parasite. It lives upon the organic food which the Alga is able to manufacture in virtue of its chlorophyll, but without obvious injury to the Alga. Indeed, the algal cells often attain to a larger size and greater brilliance of colour than when growing freely. On the other hand, the Alga is nowhere in contact with the substratum (being inclosed in the substance of the Fungus), so that water

and dissolved salts are absorbed and supplied it by the Fungus. It is also protected by the Fungus, and able to exist in places where it could not live alone. Thus, for the Lichen, we speak of *symbiosis,* a living together. 'Tis true the Fungus is the predominant partner in this association, but it is not a parasite in the common acceptation of that term. Further, as predominant partner it is the Fungus which determines the form of growth and takes the initiative, the Alga following after. But even to this rule an exception has been found, and very likely others exist. For where two organisms live together, as in the Lichen, it may well happen that conditions may exist under which the Fungus can only control the Alga with difficulty, and that the Alga, attempting as it were to escape, compels the Lichen-fungus to follow it, not to lead. This indeed seems to be the case in one of the forms of that most remarkable of all Lichens, *Cora pavonia,* to be referred to below.

The conception of the Lichen as a dual organism, compounded of Fungus and Alga, is of relatively modern origin. Its establishment is due to the researches of Schwendener, which date back some thirty years, and to those of Bornet, which shortly followed them. Since those days the continued study of Lichens has tended only to secure for the "Schwendenerian theory" (as it was formerly termed) a more wide and universal recognition. Previous to the Schwendenerian epoch the Alga was regarded as a definite portion of the Lichen-thallus, its cells as arising from the hyphæ of the Fungus; indeed the Algæ were termed "lichen-gonidia". And for many years was the new view opposed by the majority of professed Lichenologists; but into this old controversy we have not space to enter here. It is sufficient to say that the Algæ of Lichens are referable to known genera and species of free-living Algæ, and that they have been determined for a number of cases. The Alga freed from the Lichen-fungus pursues its normal mode of life, and can then be identified; this is not always possible so long as it remains within the Lichen, owing to the change which the Fungus calls forth in it. It is a noteworthy fact that hitherto no Alga has been found so completely adapted to lichenism that it could not attain to its normal development outside the Lichen-thallus. On the other hand, Lichens have been raised from the spores of the Lichen-fungus allowed to germinate on free-growing Algæ. In this way a number of Lichens have been synthesized; and it has been shown that one and the same species of Alga could serve for several Lichens. Finally, the spores of Lichen-fungi have been grown on nutrient solutions, and have attained to advanced stages of development. In nature, however, with one exception (*Cora,* see below), it is not certainly known that any Lichen-fungus can grow independent of its Alga as substratum. We must regard the Lichen-fungi as being members of various Fungus-families which have become so specialized to a peculiar form of nutrition that under ordinary circumstances they do not develop upon anything except their Algæ. The Fungus-forms which occur in Lichens are vastly more numerous than are the Algæ; indeed the latter are drawn from relatively few families—from the Chroococcaceæ and and Nostoccaceæ of the Blue-green Algæ, and from the Protococcoideæ, Confervoideæ,

and Coleochæteæ of the class Gamophyceæ of Green Algæ. Thus the same Alga serves for many different Lichens.

Classifying Lichens according to the characters of the fungal constituent, we find members of the following families: Discomycetes, Pyrenomycetes, Hymenomycetes, and Gasteromycetes. We may therefore speak of 4 families of Lichens:

Discolichenes, *Pyrenolichenes*, *Hymenolichenes*, and *Gasterolichenes*.

Discolichenes.—All produce asci in apothecia after the manner of Discomycetes (*cf.* p. 682). The apothecia arise in numbers on the surface of the Lichen-thallus (*cf.* figs. 393 [2], 394, and 387 [2]), and the spores are formed in the asci in the usual way. In many genera the spores are multicellular. In not a few cases there are arrangements for the simultaneous distribution of the Alga-cells along with the

Fig. 392.—Lichens.

[1] Hyphæ of *Stereocaulon ramulosum* enveloping filaments of the blue-green Alga *Scytonema*; ×650. [2] *Cladonia furcata* with *Protococcus*; ×950. [3] *Coccocarpia molybdæa*, section of thallus; ×650. (After Bornet.)

ascospores, so that it shall not be left to chance for the spores to alight upon a suitable Alga. In these cases the algal cells bud actively below the layer of asci, and some are pushed up between the asci at the time when the latter reach maturity. Many Lichens possess also conidial fructifications, known as pycnidia (*cf.* p. 678). These are flask-like excavations, into which tiny conidia are budded by the lining cells. These receptacles were formerly termed spermogonia and the conidia spermatia; but the evidence that they have any such function as the terminology suggests is of the most slender description. On the other hand, these conidia have been caused to germinate and produce characteristic Lichen-thalluses in a number of cases. Pycnidia may be easily seen in the Iceland Moss (*Cetraria islandica*); they occur one in each of the tiny teeth on the margins of the ribbon-like thallus. Very common is vegetative propagation by means of brood-bodies known as *soredia*. These arise as little buds below the surface, and consist of an algal cell or two and a weft of fungal hyphæ. Being formed in quantities together they burst through to the surface as a dust-like powder and constitute the "soredia-heaps". They are distributed by the wind or washed away by rain. Both constituents of the Lichen

being present, they readily grow into fresh Lichens. In the majority of Lichens the Algæ are arranged in a definite layer or stratum (*cf.* figs. 392 [3] and 387 [2]); rarely are they distributed through the whole thickness of the thallus, as in the Gelatinous Lichens (*Collema*, fig. 393 [3]). Apart from these Gelatinous Lichens, the Discolichenes may be divided, according to their form, into Crustaceous, Foliose, and Fruticose Lichens. Crustaceous Lichens include such as are everywhere attached to their substratum (stones, bark of trees, &c.) and cannot be removed without injury. As examples may be mentioned the Lecideas, many of the Lecanoras, &c. The Foliose Lichens are not thus firmly attached; the thallus forms a shield- or ribbon-like expansion, readily separable from its substratum, as, for instance, the well-known orange Lichen *Physcia parietina*, the green-hued *Peltigera canina* (Pl. XV.), with

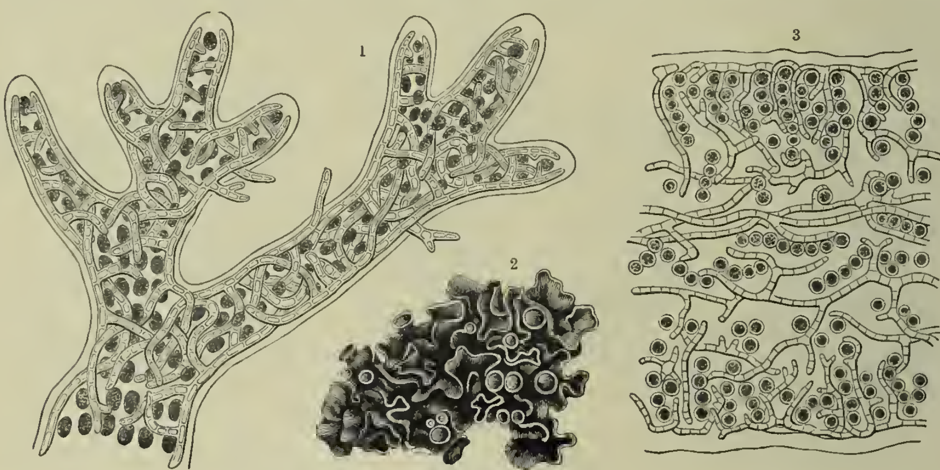
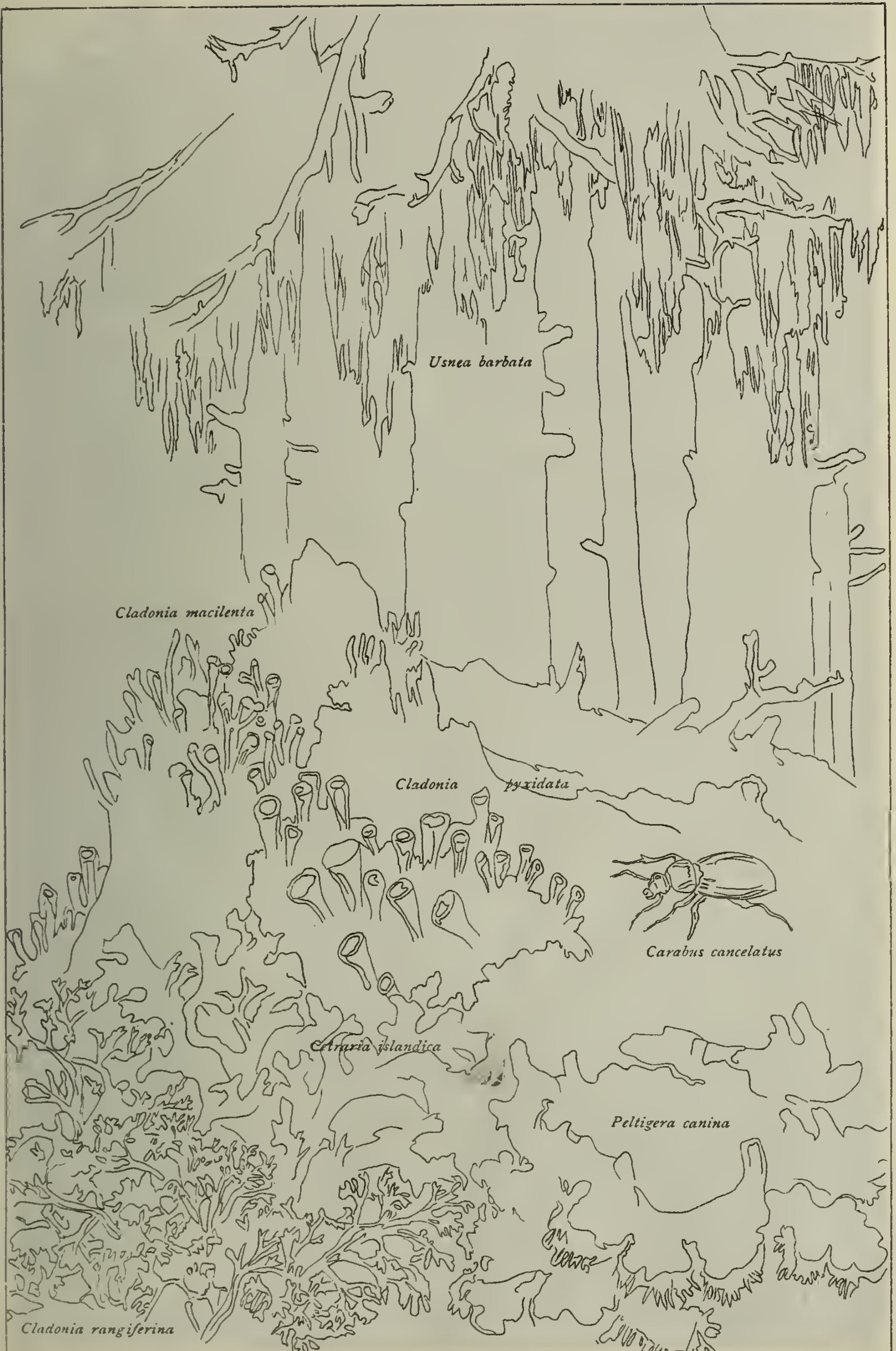


Fig. 393.—Gelatinous Lichens.

[1] *Ephebe Kerneri*; ×450. [2] *Collema pulposum*; nat. size. [3] Section of thallus of *Collema pulposum*, with *Nostoc* as Alga; ×450.

projecting umber apothecia, common in moist places amongst moss and stones, *Umbilicaria*, and many others. In the Fruticose Lichens the plant is only attached at one place, and has a shrub-like, branched appearance. Here are included many elegant and well-known forms, including *Usnea barbata*, the Old Man's Beard Lichen (Pl. XV.), which hangs in tufts and festoons from the branches of trees, and sometimes produces large disc-like apothecia the size of sixpenny pieces. Another of these epiphytic forms is *Ramalina reticulata*, a Californian form which forms beautiful gray-green, ribbon-like nets. Nor must *Cetraria islandica*, the Iceland Moss (Pl. XV.), and the Cladonias be omitted. The last-named are glaucous and generally erect-growing and branched. They include *Cladonia pyxidata*, the familiar Cup-moss (Pl. XV.), *C. rangiferina*, the Reindeer-Moss (Pl. XV.), and *C. coccifera*, growing on heaths with its scarlet, and *C. macilenta* (Pl. XV.), with orange apothecia.

Pyrenolichenes.—In these the asci are contained in perithecia as in the Pyrenomycetes (*cf.* p. 678). Otherwise they are in general agreement with the last group, and include crustaceous, foliose, and fruticose forms. There are only a


Usnea barbata
Cladonia macilenta
Cladonia pyxidata
Carabus cancelatus
Cetraria islandica
Peltigera canina
Cladonia rangiferina

FRONDOSE AND FRUTICOSE LICHENS.

Printed from the originals by the BIBLIOGRAPHISCHES INSTITUT, Leipzig.

few genera of Pyrenolichenes, including *Verrucaria, Ephebe, Endocarpon,* and *Sphærophorus.*

Basidiolichenes.—These occur only in tropical countries, and a number of genera were formerly distinguished, including *Cora, Dictyonema,* and *Laudatea.* *Cora pavonia,* the best-known form, consists of a greenish-yellow, fan-like, concentrically-striated thallus which produces its basidia on the under surface and contains *Chroococcus*-cells as its Alga; *Dictyonema,* on the other hand, consists of thin plates of rather felty consistency, in which the radiating character of the strands is very apparent; these delicate plates, blue-green in colour, stand out from the tree-branch to which they are attached. *Laudatea,* though resembling *Dictyonema,* is a crustaceous form. Both the latter forms have *Scytonema*-filaments as Algæ. Quite

Fig. 394.—*Lecanora esculenta.*

recently it has been shown by A. Möller, a naturalist who resided several years in Brazil, that all these supposed distinct Lichens are different growth-forms of one and the same Lichen. In addition to finding each of these forms in connection with the other—so that there is no doubt of their continuity—he found attached to the *Cora*-form the Fungus growing free from all trace of the Alga; this Fungus is one of the Telephoreæ (*cf.* p. 688), and when it is supplied with *Chroococcus*-cells grows into the *Cora*-form. This seems to be the only well-ascertained instance in which a Lichen-fungus has been found growing wild independent of an Alga. The *Dictyonema*- and *Laudatea*-forms consist of the same Fungus growing upon *Scytonema* instead of *Chroococcus.* In the *Laudatea*-form the Alga seems to get the upper hand and to determine the growth of the thallus. *Cora* and its various growth-forms is certainly the most interesting, as it is also the most beautiful of all Lichens of which we have any knowledge.

Gasterolichenes.—A Lichen from the Gasteromycetes has also been recognized; it is a little, shortly-stalked, puff-ball-like form resembling a *Lycoperdon* (*cf.* p. 690). The Alga (a *Palmella*) is restricted to the peripheral portions of the Lichen, which is named *Emericella variecolor.*

Phylum 3.—ARCHEGONIATÆ.

Plants showing a well-marked alternation of generations, that is of a sexual (oophyte) and an asexual generation (sporophyte). The latter reproduces the former by means of spores, the former the latter by means of egg-cells contained in archegonia. Fertilization is by means of spermatozoids which swim in water.

Class I.—BRYOPHYTA.

The sexual generation is in the greater number of cases a leafy shoot, arising from a branched, filamentous protonema. The asexual generation, which arises from the archegonium, is a stalked or sessile capsule containing spores; it is destitute of leaves, and never becomes independent of the oophyte.

Alliance XX.—**Hepaticæ**, Liverworts.

Oophyte nearly always dorsi-ventral; either thalloid or leafy. Protonema inconspicuous. Sporophyte a stalked or sessile capsule containing spores and usually elaters. A calyptra is not present.

Families: *Ricciaceæ, Marchantiaceæ, Anthocerotaceæ, Jungermanniaceæ.*

The oophyte generation in the first three families is a branched, ribbon-like, or lobed thallus (*cf.* fig. 196[1], p. 23), showing a distinction between its upper and lower surfaces, *i.e.* is dorsi-ventral. In the Jungermanniaceæ it is likewise thalloid in some forms, but in the great majority the oophyte has the form of a leafy shoot. The oophyte communicates with the substratum by means of rhizoids. The complete oophyte is preceded by an inconspicuous filamentous growth, the protonema, which arises directly from the spore, but this stage is not so well marked as in the Mosses. The sexual organs are borne usually in groups either in little depressions or upon special outgrowths of the thallus, or, in the leafy forms, are collected together into little "flowers" at the tips of the shoots or in the axils of the leaves. The female organs or archegonia are flask-shaped bodies with long necks, as in mosses. The egg-cell is contained in the enlarged basal portion, and on fertilization develops into the sporophyte or spore-capsule. The antheridia are delicate, stalked, oval or club-shaped bodies in which the 2-ciliate spermatozoids are developed. They resemble those of *Chara*, shown in fig. 374[7] (p. 660). The spore-capsule develops within the archegonium; its lower portion (in all but the simplest cases) forming a "foot" or sucker which remains imbedded in the substance of the oophyte, its upper portion forming the capsule proper. In many forms, particularly in the Jungermanniaceæ, a stalk is developed between foot and capsule, so that the latter is ultimately hoisted up. The capsule does not burst through the archegonial wall until the spores are ripe, nor is a portion of the archegonium raised up as a cap on the capsule as happens in the Mosses. The capsule ultimately opens by splitting into valves. In nearly all cases *elaters* are present with the spores. They are long thread-like cells with spiral thickening of the wall, and as they dry become very hygroscopic and

contractile. They assist in the dispersal of the dust-like spores in many cases, though the details of their co-operation in this respect is not always the same. Before the ripening of the spores the elaters play an important part in the nutrition of the spores; they are sterile cells or filaments intermixed with the spores to which they conduct food-substances during their development. Attention has been already drawn to the brood-bodies or thallidia of Liverworts (*cf.* p. 24).

Ricciaceæ.—These are very simple little forms occurring in wet places or floating in water (*Riccia natans*) like a Duckweed. The thallus is lobed or it may be ribbon-like and branched. The sexual organs are sunk in little chambers on the upper surface of the thallus; antheridia and archegonia may occur on the same or on different individuals. The fertilized egg-cell is here entirely converted into a spore-capsule, *i.e.* a sheath inclosing spores. No elaters are present in this family,

Fig. 395.

[1] Vertical section through an air-chamber of the Liverwort *Marchantia polymorpha* showing the stomate-like pore and the assimilating filaments. [2] Transverse section of a leaf of a Moss, *Barbula aloides*, showing the projecting plates of cells. [1] ×300; [2] ×380.

nor is there a sterile base or foot. The genus *Riccia* includes 107 species; there are 110 species in the whole family.

Marchantiaceæ.—The oophyte is a lobed band-like thallus (*cf.* fig. 196 [1], p. 23) with marked dorsi-ventrality. On the upper surface are a number of chambers each opening to the exterior by a single stomate-like pore (*Marchantia*, fig. 395 [1]). These chambers are really excavations of the upper surface which become closed in save for the pores in question. From the floor of each chamber sprout filaments of chlorophyll-containing cells (fig. 395 [1]); these form the main assimilating tissue of the thallus. In *Marchantia* and *Lunularia* brood-bodies (or gemmæ) are budded off in cup-like receptacles (*cf.* fig. 196 [1], p. 23). The sexual organs in this family are borne on special receptacles on the upper surface of the thallus. These may be either shield-like or stalked and umbrella-like (as in *Marchantia*, *Fegatella*, &c.). The male and female organs respectively occur on separate receptacles and are variously arranged. There are special sheathing structures associated with the archegonia. The sporophyte generation or sporogonium has a sterile base or foot which remains embedded in the archegonium. The spore-capsule is joined to the foot by a narrow, isthmus-like neck. The capsule opens by splitting into teeth. Elaters are present. Considerable variety is shown in this family in the form of the receptacles of the sexual organs.

165 species have been distinguished.

Anthocerotaceæ.—The oophyte has the form of a little lobed disc, in depressions of the surface of which the antheridia and archegonia are sunk. The sporogonium is long and cylindrical, and is invested in a circular sheath at its base. The spore-layer has the form of a hollow cylinder, leaving a sterile, central strand of tissue (the columella). Elaters are present amongst the spores, and serve as nutritive tissue for them rather than as instruments of dispersal. In this group

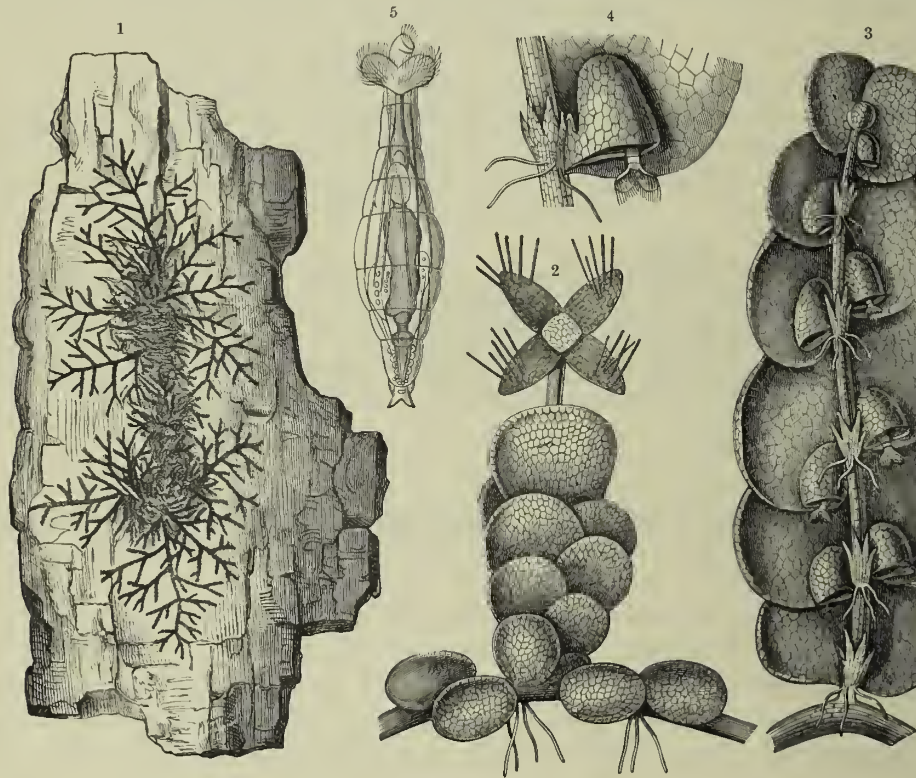


Fig. 396.—Jungermanniaceæ.

[1] *Frullania dilatata* growing on the bark of an Acer. [2] A small portion of this plant enlarged; it shows the stalked spore-capsule burst into four valves; attached to the valves are the elaters. [3] A shoot of the same *Frullania* seen from the under side; at the base of each leaf is a little pitcher containing a Rotifer. The little toothed scales lying on the stem are the amphigastria. [4] A single pitcher and its contained Rotifer. [5] The Rotifer (*Callidina symbiotica*) removed from the pitcher. [1] nat. size; [2] ×20; [3] ×25; [4] ×30; [5] ×100.

—alone amongst the Liverworts — stomates occur upon the spore-capsule. It dehisces into two valves.

There are 103 species.

Jungermanniaceæ.—Include both thalloid forms, in which the oophyte generation has a general resemblance to that of a *Marchantia*, and creeping leafy forms (*cf.* fig. 396 [1]); the latter are by far the more numerous. The sporogonium in both cases consists of a long-stalked capsule which splits into four valves (fig. 396 [2]). Elaters are present, often attached to the capsule-wall. The Jungermanniaceæ grow for the most part on damp earth, stones, and bark of trees.

The thalloid forms include the very common *Pellia*—like a *Marchantia*, with

long-stalked capsules inserted on its thallus—*Metzgeria*, branched and ribbon-like, the curious aquatic *Riella* with its spiral membrane (see fig. 366, p. 611), and the rather complex *Symphyogyna* and *Pallavicinia* (chiefly tropical), with their creeping rhizomes and stalked fronds; these two forms, almost unique amongst the Liverworts, show a well-marked vascular system. The antheridia and archegonia are scattered over the surface of the thallus and not on stalked receptacles as in the Marchantiaceæ.

The *leafy* forms are very numerous and, as a rule, consist of branched axes which lie parallel to the substratum (e.g. *Frullania dilatata*, fig. 396 [1]). There are three rows of leaves, two towards the upper surface and one towards the lower. These ventral leaves, which are termed *amphigastria*, are tiny and scale-like (see fig. 396 [3]), and sometimes are only represented by hairs. The archegonia are usually borne in little groups at the tips of the main or lateral shoots, and are inclosed in involucres. The antheridia occur in various positions. The sporogonium is always a long-stalked capsule as in the thalloid forms. Not a few of the leafy Jungermanniaceæ produce curious little appendages or "auricles" at the bases of their leaves, and these are often developed into little pitchers (fig. 396 [3]). In other cases the amphigastria bear pitcher-like appendages of the same kind. These structures seem to be receptacles for the holding of water by capillarity against times of drought. In some forms Rotifers inhabit these pitchers (e.g. *Frullania dilatata*, figs. 396 [4] and 396 [5]), but there is no evidence to show that the Liverwort uses their bodies as food like ordinary pitcher-plants, or that any special relations exist between the Rotifers and the Liverwort. The pitchers are not gall-structures directly produced by the Rotifer—they develop equally well with or without them. They are probably formed by the plant simply for storing water, and are found by Rotifers and other small animals to be convenient abiding-places.

There are more than 3500 species of Jungermanniaceæ

Alliance XXI.—**Musci**, Mosses.

The oophyte generation is the leafy moss-plant; it arises as a lateral bud from the simple and generally filamentous protonema. The sporogonium has a seta and spore-capsule, the latter usually possessing a central sterile mass of tissue, the columella. The upper portion of the archegonium is often raised as a calyptra by the elongating sporogonium.

Families: *Sphagnaceæ*, *Andreæaceæ*, *Archidiaceæ*, *Bryaceæ*.

Sphagnaceæ.—These are the Bog-mosses, and they include a single genus, *Sphagnum*. The form of the protonema here depends on whether the spore germinates in water or upon a solid substratum; in the former case it is branched and filamentous, in the latter it is a cellular expansion, not unlike a fern-prothallium. The leafy moss-plant arises by budding from the protonema, and is remarkable on account of its water-retaining properties. The character of the leaves has been already described and figured at vol. i. p. 219. The sexual organs arise on special

shoots at the apex of the plant (fig. 397 [14]); these shoots are respectively male and female, and may occur on the same or on different plants. The antheridia are in the axils of the leaves of the male shoots, the archegonia in groups at the tips of the female shoots. The fertilized egg-cell develops into the sporogonium, the lower portion of which forms a large foot, whilst the upper part swells up into the spore-

Fig. 397 —Mosses.

[1] *Polytrichum commune*; the spore-capsule to the left is concealed by the cap (calyptra), that to the right is exposed. [2] The same moss in an earlier stage of development. [3] Spore-capsule of *Polytrichum commune* with its lid. [4] The same after the falling away of the lid. [5] *Bryum cæspiticium.* [6] Spore-capsule of same with its calyptra. [7] The same after removal of the calyptra. [8] The same after removal of the lid, showing the teeth (peristome). [9] A portion of the peristome, enlarged. [10] Antheridia, archegonia, and paraphyses of *Bryum cæspiticium.* [11] *Hylocomium splendens.* [12] Spore-capsule of same. [13] *Andreœa rupestris* with burst spore-capsule. [14] *Sphagnum cymbifolium*; the spore-capsules are still intact in the left-hand specimen. [15] A single capsule of the same. 1, 2 5, 11, 14, natural size; 3, 4, 6, 7, 8, 12, 13, 15 $\times 5$; 9, 10 $\times 150$.

capsule. The spore-layer in the latter has the form of a hemispherical shell. Ultimately the archegonium is burst irregularly by the enlarging sporogonium, and the spores are set free by the removal of a circular lid at the summit.

In *Sphagnum* a true seta is not developed, the region between foot and capsule remaining quite short. The same result, however, is achieved by a considerable

elongation of the axis of the female shoot taking place in the region immediately below the group of archegonia. The capsule is thus hoisted up on a long stalk, though this stalk is no part of the sporogonium (*cf.* fig. 397 [15]).

The remains of the Bog-mosses form an important constituent of peat.

Andreæaceæ.—A small family, including the single genus, *Andreæa.* They are amongst the first settlers upon new and inhospitable rock-surfaces, and play an important part as soil-formers (*cf.* vol. i. p. 266). In them the mode of bursting of the spore-capsule is altogether peculiar amongst Mosses. Four longitudinal slits

Fig. 398.—Mosses.

1 A germinating spore. [2] A Moss-protonema. [3] Protonema giving rise to a bud from which will arise a leafy moss-shoot. [4] Longitudinal section of the tip of a male shoot of a Moss; small, club-shaped antheridia are present between the scales. [5] Tip of a female shoot with archegonia; two of them containing sporogoniums have enlarged, and in the left-hand one of these two the upper part of the archegonium (calyptra) has been torn from the basal portion. [6] Leafy female shoot bearing a fully developed sporogonium; the calyptra is still in position. [1], [2], [3] × 350 – 400; [4] × 15; [5] × 80; [6] × 5.

arise in its wall, and the four valves remain attached to one another at the apex (*cf.* fig. 397 [13]).

Bryaceæ.—This family includes the vast majority of the Mosses. The germinating spore produces a simple, branching, filamentous protonema (figs. 398 [1] and 398 [2]) on the surface of the ground, certain of its branches developing as colourless rhizoids and penetrating the substratum. From the protonema the ordinary leafy Moss-plant arises as a lateral bud (*cf.* fig. 398 [3]). The curious properties of the protonema of the Luminous Moss (*Schistostega osmundacea*) have been already described (*cf.* vol. i. p. 385, and Pl. I. fig. p). The leafy shoots become rooted by the development of rhizoids from their lower extremities, and bear their leaves, as a rule, in three rows, though a slight twisting of the stem often disguises this fact.

The Luminous Moss just mentioned is an exception; in it the leaves are arranged in two rows (*cf.* fig. 399^{9}). The leaves of Mosses are generally simple, and (unlike the Jungermanniaceæ) provided with midribs. In many of the Polytricheæ, and in *Barbula aloides*, &c. (*cf.* fig. 395^{2}), the upper surface of the leaf bears longitudinal ridges of thin-walled chlorophyll-containing cells, thus adding to its assimilating and transpiring surface. The Moss-plant can propagate freely by means of brood-bodies and gemmæ. These sometimes take the form of modified leaves, sometimes of little stalked bodies on the leaves; occasionally they are collected together into little receptacles at the tips of the shoots, as in *Tetraphis* (*cf.* fig. 196, p. 23, where this and other cases are illustrated). The antheridia and archegonia are collected into little receptacles or "flowers" placed either at the tips of the shoots (in the *acrocarpous* Mosses, *cf.* figs. 397^{1} and 398^{6}), or laterally in the leaf-axils (in the *pleurocarpous* Mosses, *cf.* fig. 397^{11}). Occasionally both antheridia and archegonia are present together in the same "flower" (*cf.* fig. 397^{10}), but more frequently they are in separate receptacles (*cf.* figs. 398^{4} and 398^{5}). Mingled with them are sterile scales, the paraphyses. The structural details of the sexual organs and the mode of fertilization in Mosses has already been described (*cf.* pp. 64–66). After fertilization the egg-cell within the archegonium divides and enlarges, and gradually fashions itself into the sporogonium, the asexual generation of the Moss. For a time the archegonium stretches with the growing embryo, but sooner or later it is ruptured (*cf.* fig. 398^{5}), and its upper portion raised aloft on the sporogonium as the calyptra. Sometimes the calyptra forms a closely-fitting cap, entirely investing the capsule as in *Polytrichum* (fig. 397^{1}), or it may be a little hood split down one side as in *Bryum* (figs. 397^{6} and 398^{6}). After the raising of the calyptra by the elongation of the stalk or seta of the sporogonium the apex swells and develops into the capsule. Though in almost all cases the sporogonium consists of a capsule borne on a long smooth stalk (the seta), which is embedded below in the tissues of the female shoot of the Moss-plant, a very considerable amount of variety is met with in the structural details of the capsule itself. The seta may pass gradually into the capsule as in *Bryum* (fig. 397^{6}), or there may be a bulb-like enlargement (apophysis) at the base of the capsule as in *Polytrichum* (fig. 397^{3}), or this enlargement may attain considerable dimensions, exceeding the spore-producing part of the capsule, as in *Splachnum* (fig. 399). This apophysis is of importance as an assimilating and transpiring organ, and it is the only portion of the whole Moss which bears stomata. Within the capsule is the spore-layer. This has the form of a hollow cylinder surrounding a central sterile tissue, the columella. External to the spore-layer, and between it and the wall of the capsule, is a lacuna generally traversed by chlorophyll-containing filaments of cells. Above the spore-layer the columella expands into a mass of tissue, which forms the lid of the capsule (operculum, *cf.* figs. 397^{3} and 397^{7}). At the periphery of the lid, where it abuts upon the wall of capsule, a ring of cells becomes marked out (the annulus); later, by the rupture of this ring the lid comes away, and the mouth of the capsule is guarded only by a set of teeth, the peristome (*cf.* figs. 397^{8}, 397^{9}, 399^{3}, and 399^{8}). By the time that the lid is ready to come

away the spores are ripe, and the columella, &c., have dried up and collapsed. The teeth of the peristome are exceedingly varied in pattern in the various genera of Mosses; typically there are two series of them forming an outer and an inner peristome (*cf.* fig. 397 [9]), but they are differently thickened, fused, and divided, and one or even both series (e.g. *Gymnostomum*), may be absent. They are very hygroscopic, and their function will be alluded to later on when we are discussing the

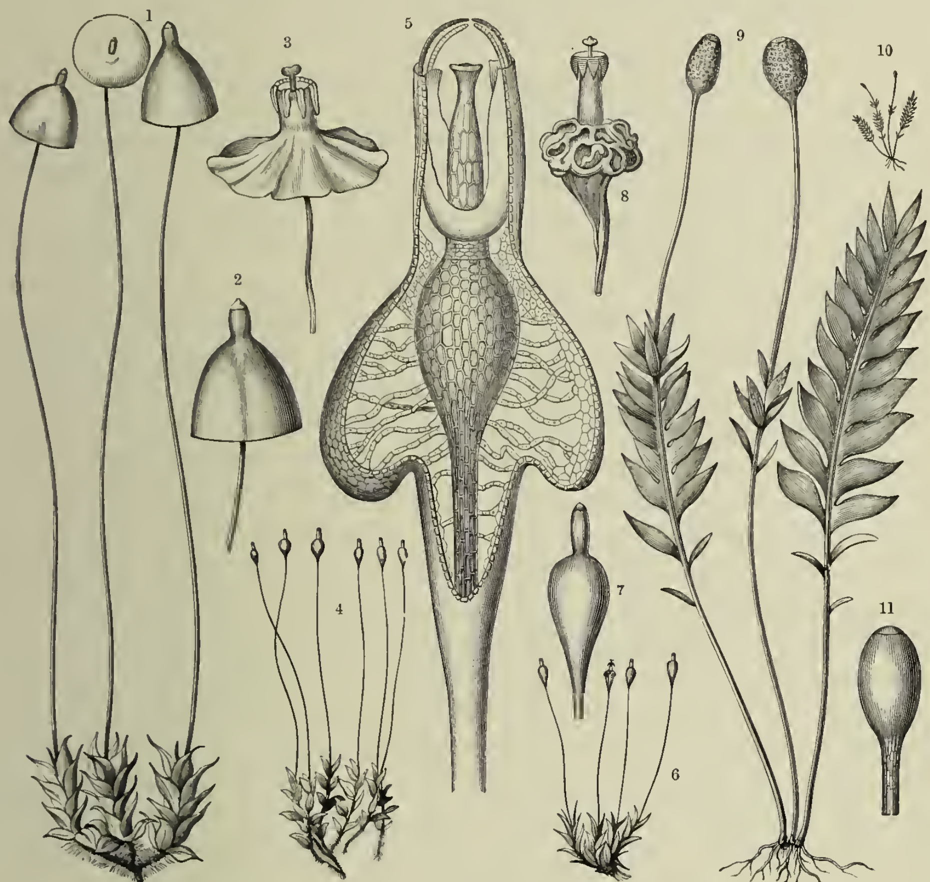


Fig. 399.—Spore-capsules of Mosses.

[1] *Splachnum luteum.* [2] An unripe capsule of the same. [3] A ripe and open capsule of the same. [4] *Splachnum vasculosum.* [5] Longitudinal section of a ripe capsule of this moss, showing the large apophysis below containing lacunæ, and traversed in the middle by the columella; above is the capsule proper with persistent columella, spore-sac, and peristome. [6] *Splachnum ampullaceum.* [7] An unripe capsule. [8] A ripe capsule of the same. [9] and [10] *Schistostega osmundacea.* [11] A ripe capsule of the same. [1], [4], [6], [10] natural size; [2], [3] × 2; [7], [8], [9] × 10; [11] × 15; [5] × 100.

distribution of spores. In the Polytricheæ the peristome is not quite the same as in other Mosses. In this group the teeth are very numerous and quite short, and from their apices a membrane (the epiphragm) remains stretched after the fall of the lid (*cf.* fig. 397 [4]). The spores here tumble out between the teeth.

The position of the sporogonium is of course determined by that of the female "flowers"; where these are terminal the sporogonium will be terminal (acrocarpous), similarly where lateral (pleurocarpous). The number of genera of Bryaceæ is so

numerous that it is hardly possible to mention even the most notable here. *Fontinalis* is of interest in being aquatic; *Splachnum* (*cf.* fig. 399) in having a very large apophysis and being saprophytic on animal excreta (*cf.* vol. i. p. 118). *Buxbaumia aphylla* is an exceedingly simple form and vegetates in the protonema-stage. Leafy shoots are only formed in connection with sexual reproduction, and even then they are very rudimentary. This plant has been thought to be a primitive type of Moss.

Fossil Mosses are met with in Tertiary and more recent deposits.

Class II.—PTERIDOPHYTA, Vascular Cryptogams.

As in the Bryophyta, so here, a well-marked alternation of generations is exhibited in the life-history. Whilst in the Liverworts and Mosses the oophyte is the dominant stage ("the plant") here the sporophyte constitutes "the plant". The oophyte is a mere prothallium of simple nature, the sporophyte is a complex structure with root, stem, and leaves, and a well-marked vascular system. It becomes free from the prothallium at an early stage in development. The Pteridophyta contain the following alliances: *Filices, Hydropterides, Equisetales, Lycopodiales.*

The plant or sporophyte generation attains to a wide diversity of form in the Pteridophytes; thus, amongst the Ferns the stem is often short and bears a rosette of fronds, or is elongated and rhizome-like with leaves at intervals; in the Equisetales it is erect and jointed, and the leaves are reduced to toothed sheaths; and in many Lycopodiales the stem is procumbent, much-branched, and covered with simple scale-like leaves over the entire surface. Upon the leaves are borne the sporangia which contain the spores. The sporangia may be either scattered over ordinary leaves or on special leaves collected into cones. There is one feature connected with the spores that must be described here. Though in the Ferns and in many other Pteridophytes all the spores are of one kind and each gives rise to a prothallium bearing both archegonia and antheridia, there are Pteridophytes in the alliances Hydropterides and Lycopodiales in which two sorts of spores are produced. The latter are known as heterosporous, the former as homosporous. Where the plants are heterosporous the spores are of two sizes, and the larger ones (macrospores) are contained in fewer numbers in the sporangia than are the smaller ones (microspores). On germination the macrospore gives rise to a female prothallium only, the microspore to a male prothallium; *i.e.* growths which bear respectively archegonia and antheridia. The male prothallium is a very simple structure, and its part is played so soon as it has liberated its spermatozoids. The female prothallium having to nourish the young sporophyte for a while, until such time as it can live independently, is larger, and is usually well-provided with food-material.

Contrasting the Pteridophytes and Bryophytes, the Fern-plant corresponds to the sporogonium of the latter and the prothallium to the Moss-plant or Liverwort thallus. In the former the sporophyte, in the latter the oophyte generation is the more complex. But that a Fern-plant has been elaborated out of a Moss-sporogonium, or that the Fern-prothallium is a reduced or degraded Moss-plant, is exceed-

ingly improbable. It is more likely that the two groups have had a common origin, and have then developed along entirely different lines

Alliance XXII.—Filices, Ferns.

Families: *Hymenophyllaceæ, Polypodiaceæ, Cyatheaceæ, Gleicheniaceæ, Schizæaceæ, Marattiaceæ, Osmundaceæ, Ophioglossaceæ.*

With us for the most part Ferns have short underground stems bearing a rosette of leaves as in the Male Fern (*Aspidium Filix-mas*) and Hart's-Tongue Fern (*Scolopendrium vulgare*), or there may be an elongated horizontal underground rhizome, as the Bracken Fern (*Pteris aquilina*) and Polypody (*Polypodium vulgare*), the leaves being produced at intervals. In the tropics and sub-tropical regions, on the other hand, Tree Ferns are common. They belong mostly to the genera *Cyathea, Alsophila,* and *Dicksonia.* In these a considerable caudex is developed (*cf.* fig. 347, p. 473, and vol. i. p. 714), which is often enveloped in a perfect plexus of aërial roots. Many Ferns are epiphytic, especially in tropical forests (e.g. *Platycerium alcicorne,* fig. 349, p. 475); with us *Polypodium vulgare* is often met with enveloping the trunks and boughs of large trees. The tropical genus *Lygodium* is characterized by its climbing habit, the long rachis of its compound leaf twining like the stem of a twining plant. The view has been held, and is alluded to on p. 12, that the fronds of Ferns are not really leaves but modified stem-structures, the scaly structures that occur on the stem and fronds being regarded as the true leaves. It is sufficient to say that this view is not very widely held amongst Botanists, and that here the term leaf is used as synonymous with frond. Broadly speaking, Ferns love moist and shady habitats; they grow especially in woods and forests, and on humid rocks beside streams, &c. Generally their leaves are thin and delicate, and ill-adapted to withstand prolonged desiccation.

Borne on the leaves of Ferns are the sporangia, tiny capsules in which the spores are developed. The form of the sporangium and the arrangement of these bodies varies in the different families of Ferns—indeed the sporangia afford characters which are used for the grouping and classification of Ferns. In the commonest Ferns (belonging to the predominant family Polypodiaceæ) the sporangium resembles two watch-glasses placed together, the rim being occupied by a series of large, thick-walled cells (the annulus), and the whole mounted on a little stalk (*cf.* fig. 400 [14]). In other families the stalk may be absent, the annulus incomplete, oblique, transverse or altogether wanting, &c., as will be pointed out in treating the several families. The sporangia are aggregated into clusters, the sori, and these are in many cases protected by little outgrowths of the leaf-surface (indusia) or under the infolded margins of the leaf. The form and arrangement of the sori and indusia provide the characters according to which the large family Polypodiaceæ is subdivided.

Hymenophyllaceæ.—The Filmy and Bristle Ferns. There is generally a rhizome which bears delicate fronds at intervals (*cf.* fig. 400 [2]); the lamina of the

leaf is often only one cell thick, and stomata occur only in the genus *Loxsoma* (New Zealand). The other genera, *Hymenophyllum* (the Filmy Fern) and *Trichomanes*, are both met with in Great Britain. The former is not uncommon on the rocks beside waterfalls, but the latter (*Trichomanes radicans*, the Killarney Fern) seems to be almost restricted to the south of Ireland. In this family the sporangia occur at the margins of the fronds on the excurrent veins (see fig. 400 [8]). They are sessile, and the annulus is transverse, *i.e.* at right angles to the axis of the sporangium. The sorus is surrounded by an enclosure formed from the leaf-margin; this investment is cup-shaped in *Trichomanes* and bivalved in *Hymenophyllum*. Often in the former genus the axis on which the sporangia are inserted projects considerably from the cup—hence the name Bristle Fern. In this family the prothallium is unlike that of other ferns, being frequently filamentous and branched; the filaments often bear local expansions, upon which the archegonia are inserted.

There are about 200 species of Hymenophyllaceæ.

Polypodiaceæ.—By far the largest family of Ferns; indeed this family includes more than three times as many species as all the rest of the Pteridophytes together. Almost all our familiar European Ferns belong to it. The character which they all have in common is a stalked sporangium (fig. 400 [14]), with vertical annulus. The distribution and form of the sori are exceedingly various. The Polypodiaceæ have been separated into the following tribes:—*Pterideæ, Aspidieæ, Asplenieæ, Davallieæ, Polypodieæ, Grammitideæ, Acrosticheæ.* In the *Pterideæ* the sori occur at the margin of the leaf; in the Bracken Fern (*Pteris aquilina*) the frond is much branched, and the sori are everywhere continuous on the pinnule-margin; they are covered in by an indusium derived from the margin; in the Maiden-hair Fern (*Adiantum Capillus-Veneris*) the tip of the pinnule is folded back over the sorus. In the *Aspidieæ* the sori are scattered, circular, and covered in by a circular or kidney-shaped indusium. *Aspidium Filix-mas* (the Male Fern) belongs to this tribe. The sorus is much elongated and linear in the *Asplenieæ*, and the indusium is inserted on one side of it (e.g. *Asplenium Ruta-muraria*, figs. 401 [6] and 401 [7]). The Lady Fern (*Athyrium Filix-fœmina*), Hard Fern (*Blechnum*), Hart's-tongue (*Scolopendrium*), &c., are members of this tribe. In the *Davallieæ*, which include the large tropical genus *Davallia*, the sorus is near the margin, and inclosed in a pocket-like indusium. In the *Polypodieæ* the sori are circular and scattered over the under surface of the frond. There is no indusium (see fig. 400 [5]). The *Grammitideæ* resemble the last-named in the absence of an indusium. The sori usually follow the veins, frequently forming very elegant reticulations on the under surface of the leaf, as in the tropical genus *Hemionitis*. The Gold and Silver Ferns (*Gymnogramme*) belong to this tribe. In the *Acrosticheæ* the whole under surface is covered with sporangia, and there is no indusium. Examples are, *Rhipidopteris* (fig. 400 [4]), *Platycerium* (fig. 349, p. 475), and *Acrostichum*.

Nearly 3000 species of Polypodiaceae are known.

Cyatheaceæ.—This family includes the Tree-ferns (fig. 347, p. 473). The annulus of the sporangium is slightly oblique; it is only indifferently represented in

Fig. 400.—Various Ferns.

[1] *Nephrolepis Duffi.* [2] *Trichomanes Lyallii.* [3] Sorus of the same fern, with cup-shaped investment seen in longitudinal section. [4] *Rhipidopteris peltata.* [5] *Polypodium serpens.* [6] Portion of frond of *Gleichenia alpina.* [7] *Schizæa fistulosa.* [8] *Botrychium lanceolatum.* [9] Under side of a fragment of the frond of *Gleichenia alpina*; above the sporangia are concealed by a tuft of scales, below they are exposed. [10] and [11] Fertile pinnule of *Cyathea elegans.* [12] Longitudinal section of a sorus of *Cyathea.* [13] Sporangium of *Cyathea.* [14] Sporangium of *Polypodium.* [15] Sporangium of *Schizæa.* [16] Under side of the prothallium of *Asplenium.* 1, 2, 4, 5, 6, 7, 8 natural size; 3, 9, 10, 11, 12, 13, 14, 15, 16 × 5–20.

fig. 400 [13]. In *Cyathea* (figs. 400 [10, 11, 12]) the indusium is cup-like, and closed until the spores are ripe. In *Dicksonia* the sorus is marginal, with bivalved indusium; in *Alsophila* the sori are scattered, and the indusium absent or rudimentary; in *Hemitelia* the indusium is scale-like, and situated on one side of the sorus. Of Cyatheaceæ about 200 species are known.

Fig. 401.—Life-history of a Fern.

1 A Fern-prothallium seen from the under side. 2 An archegonium in longitudinal section. 3 An antheridium. 4 Escape of spermatozoids from antheridium. 5 Young sporophyte with first leaf arising from the prothallium. 6 Complete sporophyte of *Asplenium Ruta-muraria*. 7 Under surface of pinnule of same, showing linear sori and lateral indusia. 8 A young prothallium arising from a spore; the spore is below. 6 natural size; 1 × 8; 2, 3, 4 × 350; 5 × 6; 7 × 3; 8 × 240.

Gleicheniaceæ.—Mostly tropical forms. The sporangia have a transverse annulus, and are collected into little sori of 3 or 4 sporangia, often very closely packed (*cf.* figs. 400 [6], and 400 [9]). The frond usually forks repeatedly. There is only one genus, *Gleichenia,* which has some 40 species.

Schizæaceæ.—The members of this family are also for the most part tropical.

The sporangium is sessile, and the annulus is situated at the apex like a cap (*cf.* fig. 400 [15]). In *Schizœa* (fig. 400 [7]) the fertile pinnules bear two rows of sporangia partly sunk in little pockets; in the climbing fern *Lygodium* the leaflets bear little fertile spikes at the margin, and the sporangia are sunk completely in little pockets, one row on either side of the spike. In *Aneimia* the frond divides into two portions—a green vegetative portion, and several fertile branches whose ultimate ramifications are beset with naked sporangia. In habit *Aneimia* is not unlike a *Botrychium* (*cf.* fig. 400 [8]). Of Schizæaceae there are some 70 species.

Marattiaceœ.—Tropical Ferns, many of them attaining considerable dimensions. The fronds are distinguished by possessing a pair of stipules at their base. The sporangia are more bulky than in the families hitherto enumerated, and in *Angiopteris* are arranged in rows very close together, whilst in *Marattia*, *Kaulfussia*, &c., all the sporangia of each sorus are joined together into little button or bean-like bodies. There is no distinct annulus, though a little cap of cells possibly represents one. There are 25 existing species, but this family was much more abundant, than it now is, in palæozoic times; their remains are abundant in the Coal Measures.

Osmundaceœ.—Here also the sporangium is destitute of annulus, and possesses a little cap of cells in place of it. In *Osmunda regalis*, the Royal Fern, the upper pinnules of the frond alone produce sporangia, but in such quantity that their whole surface is covered with them; thus the tips stand out in marked contrast to the rest of the frond (hence the name "Flowering Fern"). The other genus of the family, *Todea*, resembles a Filmy Fern in the delicate texture of its leaves. There are only 11 species altogether.

Ophioglossaceœ.—A small family including the Adder's-tongue (*Ophioglossum*) and Moonwort (*Botrychium*). The frond here divides into a sterile and a fertile portion, the latter seeming to arise from the base of the former. In the Adder's-tongue the sterile portion is unlobed, and the fertile portion spicate, the sporangia being sunk in its substance. In the Moonwort (*cf.* fig. 400 [8]) both parts are branched, the fertile portion resembling a panicle. The prothallium in this family is a little subterranean tuberous body. The origin from it of the sporophyte generation has not followed in any instance. There are twelve species of Ophioglossaceæ.

Alliance XXIII.—Hydropterides, Rhizocarps.

This alliance is nearly associated with the Filices and more particularly with the earlier rather than with the last-mentioned families of that alliance. All the genera are more or less aquatic in habit; but their distinctive feature is the fact that they are *heterosporous*, *i.e.* that some sporangia contain macrospores (one in each sporangium) the others microspores. The sporangia are collected into sori, which are inclosed by metamorphosed leaf-segments into little fruit-like bodies.

Families: *Salviniaceœ*, *Marsiliaceœ.*

All the members of the alliance agree in their aquatic habit and in being heterosporous. The macrosporangia are larger than the microsporangia, and contain one

big oval macrospore; the microspores are produced in numbers in the microsporangia. The macrospore, in addition to a hard wall, possesses an external gelatinous layer with stratified structure. On germination, the macrospore develops its (female) prothallium at one end, and, on the bursting of the spore-wall at the apex, this prothallium and the archegonia developed on its surface, are exposed. Of the contents of the spore, only a portion forms the prothallium, the rest remaining as a reserve mass. The microspores, which are usually embedded in mucilage, undergo several divisions (forming antheridia), and liberate spermatozoids, which fertilize

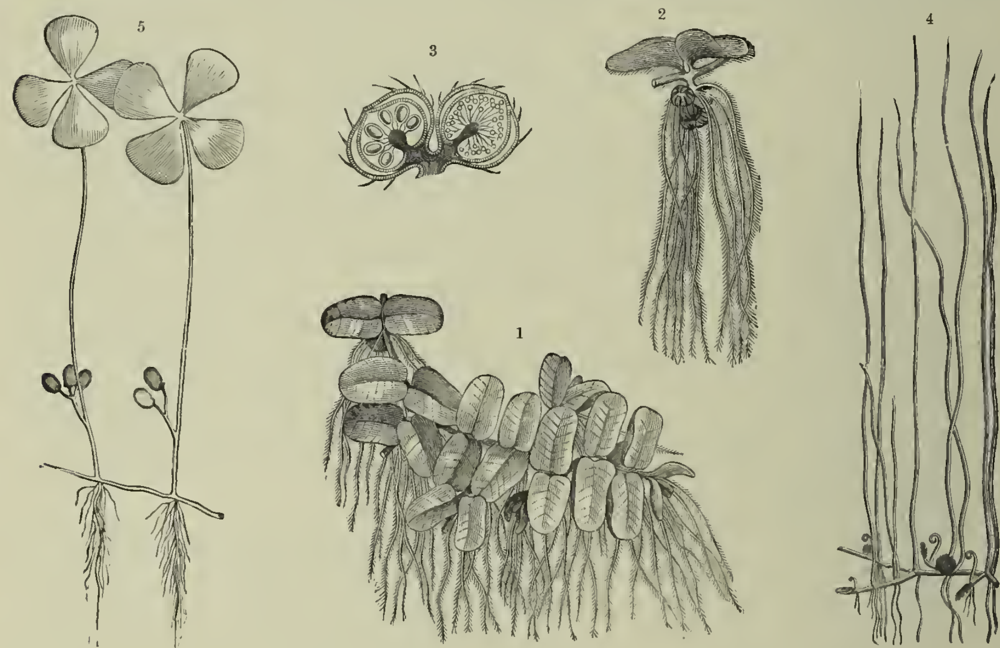


Fig. 402.—Hydropterides.

[1] *Salvinia natans*, showing the floating and submerged leaves. [2] A portion of the same seen from the side, and showing the sporocarps at the base of the submerged leaves. [3] A section through two sporocarps of *Salvinia natans*; that to the left contains macrosporangia only, that to the right microsporangia. [4] *Pilularia globulifera*; one or two sporocarps are shown at the base of the needle-like leaves. [5] *Marsilia quadrifolia*, showing sporocarps. [3] × 4; the rest, natural size. (After Luerssen.)

the archegonia. From one of the archegonia the young sporophyte arises, and gradually develops into the adult form.

Salviniaceæ.—Include two genera, *Salvinia* and *Azolla*, both of which are floating plants. The former occurs in Southern Europe, the latter, though hardy in Europe, is a native of America, Australia, &c. *Salvinia* (figs. 402 [1] and 402 [2]) has a stem which lies horizontally on the water, and develops both floating and submerged leaves. The latter divide into numerous filaments, which hang down like tassels in the water (*cf.* fig. 402 [2]). They are the absorptive organs of the plant, and play the part of roots. True roots, however, are wanting, even from the embryo. The sporangia are borne on these submerged leaves close to the point of attachment to the horizontal stem, generally in three groups or sori, each of which is inclosed in a cup-like upgrowth arising from the submerged leaf (*cf.* fig.

402 [3]). The arrangement of the sori is not unlike those in *Trichomanes* (*cf.* fig. 400 [3]), except that the cup is closed round the sorus. In each sorus occur only macrosporangia or microsporangia; but in each group of three sori usually one is different from the other two. Each sorus with its investment constitutes a sporocarp. The other genus, *Azolla*, resembles a floating, leafy Jungermannia (*cf.* fig. 396 [1], p. 698); it is closely set with tiny leaves, and numerous true roots hang down into the water. The macrospores are provided with a floating apparatus and hooks; and the microspores which escape from their sporangia in packets have long barbed appendages, which become attached to the hooks of the macrospores. Thus the spermatozoids escape in the immediate neighbourhood of the female prothallia.

There are 9 species of Salviniaceæ.

Fossil residues occur in the tertiary formations.

Marsiliaceæ.—Containing the two genera, *Pilularia* and *Marsilia.* Both grow in marshy or inundated ground, and spread their rhizomes horizontally, attaching them by means of roots. The leaves in *Pilularia* (fig. 402 [4]) are needle-like, and each bears at the base a very short branch which develops into a sporocarp. In *Marsilia* (fig. 402 [5]) the leaves resemble those of *Oxalis*; near the base they give off a branch which may bear several bean-like sporocarps. The sporocarps in both these plants do not—as in the Salviniaceæ—consist of mere sori with an investment; but each is a leaf-segment in which a number of cavities develop (four in *Pilularia*, many in *Marsilia*), cavities which ultimately are quite cut off from the exterior, though they arise at first as pittings of the surface. In these cavities groups of sporangia arise—both macro- and microsporangia in each chamber. The sporocarp in this family is, therefore, in nature a leaf-lobe containing numbers of sporangial cavities, and of much greater complexity than in the Salviniaceæ. The sporocarps ultimately dehisce, the spores develop their prothallia, and fertilization takes place. There are 32 species of *Marsilia* and 3 of *Pilularia*. *P. Globulifera* alone is British. Fossils are found in tertiary formations.

Alliance XXIV.—**Equisetales**, Horsetails.

Possess jointed stems and small leaves inserted in whorls. The sporangia are produced on special leaves arranged in cones. All living examples are homosporous, but palæozoic forms include heterosporous genera.

Families: *Equisetaceæ*, *Calamariæ*.

The *Equisetaceæ* alone are represented by living plants, and include the solitary genus *Equisetum*, with about 40 species.

The habit of growth of the Equisetums is exceedingly characteristic. There is a branching underground rhizome from which erect aërial shoots are produced each year. From the nodes of the underground stems numerous fine roots arise (fig. 403 [2]). The whole of the aërial shoot is green and assimilating, and the leaves are represented by funnel-shaped sheaths bearing teeth inserted at the nodes. The internodes are ribbed and the whole structure harsh to the touch, and often brittle owing

to the large amount of silica contained in the epidermal membranes. The early spring shoots of many species are unbranched and terminate in spore-bearing cones (e.g. *E. arvense*, fig. 403 [2]), whilst later on other branching shoots arise which are sterile (fig. 403 [1]). In other cases the fertile shoots are also branched (fig. 403 [7]).

Fig. 403.—Equisetaceæ.

[1] Summer sterile shoot of *Equisetum arvense*. [2] Vernal, spore-bearing shoot of *Equisetum arvense*. [3] Fertile cone of the same. [4] A single sporangiferous scale (sporangiophore) of the same. [5] and [6] Spores with "elaters" expanded and coiled. [7] *Equisetum sylvaticum* with cone. [8] Prothallium of a Horse-tail with antheridia. [1], [2], [7] natural size; [3] × 3; [4] × 6; [5], [6] × 25; [8] × 30.

The branches arise from the main axis in whorls at the base of the leaf-sheaths, and in most cases perforate the latter as they develop (fig. 403 [7]). They repeat the structure of the main axis, save that they are smaller and have fewer teeth to their leaf-sheaths. *E. maximum*, common in this country in damp places, attains a height of two metres, and is the largest British representative of the group, but

E. giganteum (Tropical America) is stated to reach as much as ten metres. The Dutch Rush (*E. hiemale*) is largely used for polishing owing to the quantities of silica it contains. Characteristic of the stems of Equisetums is the large central air-space, which is only interrupted by diaphragms at the joints. Other spaces also occur associated with the vascular bundles and in the cortex, alternating with the bundles.

The spore-bearing cones (figs. 403 [2, 3, 7]) consist of stalked, shield-like leaves borne on the club-shaped termination of the axis. The scales bear numerous sporangia on their under surface (fig. 403 [4]), and in these are the curious and characteristic spores. The wall of the spore is three-layered, and the outmost layer splits away from the one below it, forming four arms attached to the spore at one point (fig. 403 [5]). These arms, termed elaters (not to be confused with the elaters of Liverworts, *cf.* p. 696) are extremely hygroscopic, and though at first coiled around the spores (fig. 403 [6]) become extended as the spores dry, and as their humidity fluctuates contract and expand again. In this way the spores become entangled with one another and are distributed in groups, arm-in-arm. The importance of this circumstance appears to be as follows:—The spores, though all of one sort (*i.e.* homosporous), give rise to diœcious prothallia as a rule (*cf.* fig. 403 [8], representing a male prothallium); consequently it is of advantage for promoting fertilization that a number of prothallia should arise in the same neighbourhood. This result is achieved by a linking of the spores. The prothallia are richly lobed, but not unlike those of Ferns.

The *Calamariæ* are found as common fossil remains in the carboniferous formations. They include casts of the medullary cavity, impressions of the surface, and actual portions of the stems and cones in a petrified state. Many members of this family attained gigantic proportions, and their stems underwent a well-marked secondary increase in thickness. An examination of the cones shows that these former Equisetales possessed both micro- and macrospores.

Alliance XXV.—**Lycopodiales**, Club-mosses.

Forms usually with elongated, branching stems and small leaves distributed over them. The sporangia are borne on the upper surface of the leaf or in the leaf-axil; the fertile leaves are in many cases aggregated into cones. Both homosporous and heterosporous families occur.

Families: *Lycopodiaceæ, Psilotaceæ, Selaginellaceæ, Lepidodendraceæ, Sigillariaceæ, Isoëtaceæ.*

Whilst in the Filices and Equisetales several or many sporangia are present on the fertile leaves, in this alliance there is only one, and this is situated on the *upper* surface or in the leaf-axil. The sporangia in this group differ from those in many of the Filices (*e.g.* Polypodiaceæ) in being more massive and in having origin not from single epidermal cells, but from a row or group. Their form also is in many cases peculiar. The Lycopodiaceæ and Psilotaceæ are homosporous, the other families heterosporous. In the former the prothallia generally resemble those of Ferns, in

the latter their condition parallels that of the Hydropterides. Lepidodendraceæ and Sigillariaceæ are represented by fossil forms only.

Lycopodiaceæ.—The Club-mosses proper include some 100 species, distributed over various parts of the globe. The habit of a typical *Lycopodium* is indicated in the accompanying figure of *L. annotinum,* with its branching stem closely set with simple, scale-like leaves and terminal cones. The species common in mountain regions in this country are *L. clavatum, L. alpinum,* and *L. Selago*; *L. annotinum*

Fig. 404.—*Lycopodium annotinum.*

(fig. 404) is also met with. Of these *L. Selago* alone is devoid of cones, its sporangia occurring on the ordinary leaves. The sporangium is generally large and kidney-shaped, and is attached to the base of the upper side of the leaf (fig. 405[4]); its concavity is directed towards the axil of the leaf. Till recently the life-history of *Lycopodium* was unknown, as difficulty was experienced in causing the spores to germinate. It was first observed in certain tropical species, *L. cernuum* and others. In this species the prothallium has the form of a tiny tuberous body, with a lobed fringe on which the antheridia and archegonia are developed. The history of development of the sporophyte from the egg has been followed and is of some interest. In *L. cernuum* the young plant consists of a tubercle bearing a tuft of

leaves above. Gradually the stem elongates and the adult form is assumed. The special interest attaching to this stage is that it is characteristic of the mature *Phylloglossum* referred to below. It has been suggested that the last-named genus is a primitive form which retains as adult character what is but embryonic in *Lycopodium.*

The genus *Phylloglossum* (found in parts of Australia and New Zealand) possesses, in addition to its tubercle and tuft of leaves, a stalk which terminates in a cone of sporangium-bearing leaves. There is only a single species.

Psilotaceæ.—Includes two genera, *Psilotum* and *Tmesipteris. Psilotum* is tropical; it has delicate, angular, forking stems, and its leaves are reduced to tiny scales. It is rootless and grows epiphytically. Its sporangia are three-chambered and are borne on reduced leaves. Vegetative bulbils are frequently met with, especially on those shoots which grow upon the substratum. *Tmesipteris* is also an epiphyte (New Zealand and Australia). It has conspicuous, pointed leaves and long, trailing stems. The ordinary leaves are simple, but the fertile ones fork like a V, and the sporangium (which is two-chambered) is inserted on the upper surface at the junction of the V. The prothallial stage is not known in either of these genera.

Selaginellaceæ.—A family of some 300 to 400 species, which are in large part tropical, and all belong to the genus *Selaginella.* The shoots are forked and are dorsiventrally flattened. The leaves are borne in four rows—two rows of smaller overlapping leaves right and left of the median dorsal line, and two rather larger ones along the edges of the stem (*cf.* fig. 111 [1], vol. i. p. 421). A very common species in the alpine regions of Europe is *Selaginella helvetica,* whilst *S. selaginoides* (= *S. spinosa*) is British. The last-named species, unlike the majority of Selaginellas, is not flattened, and its leaves are distributed around the stem as in a *Lycopodium.* A characteristic feature is the presence of a little tongue inserted in the median line of the upper surface of the leaf near its point of insertion; this is known as the *ligule.* The roots in most cases arise, not directly from the stem, but from special branches termed *rhizophores.* Selaginella is *heterosporous.* The sporangia are spherical and arise in the axils of the fertile leaves, which are collected into cones. The macrosporangia contain four macrospores, and the microsporangia numerous microspores. Both kinds of sporangia occur usually in one cone, the former below; or they may be in rows along the sides of the cones; or, finally, the two sorts of sporangia may be on different cones.

The product of germination of a microspore consists of a single, simple antheridium, containing spermatozoids, which are provided with two flagella attached to the pointed end. The macrospore produces a small, green female prothallium at one end (as in the Hydropterideæ, p. 710), whilst the rest of the spore, which here divides into large cells, serves as a reserve of food-material. The green portion bears the archegonia, and is exposed. After fertilization, an embryo arises, and gradually develops into the *Selaginella*-plant. The embryogeny presents various features of interest. In particular may be mentioned the production of a suspensor from that portion of the embryo which is towards the neck of the archegonium.

By the elongation of this suspensor the embryo proper is brought down into the aforementioned food-reserve, where it continues its development. This process is quite similar to the corresponding stage in Flowering Plants, where the suspensor is almost universally found.

Lepidodendraceæ.—This family, represented only by fossils from the Devonian and Carboniferous formations, consisted of large-growing Lycopod-like forms, with huge stems clad with linear leaves. They exhibit a secondary growth in thickness (wanting in recent Lycopods), and both micro- and macrospores were produced in the cones. Casts of *Lepidodendron*-stems bear characteristic rhomboidal areas corresponding to the leaf bases, and upon these the actual leaf-scars may be seen.

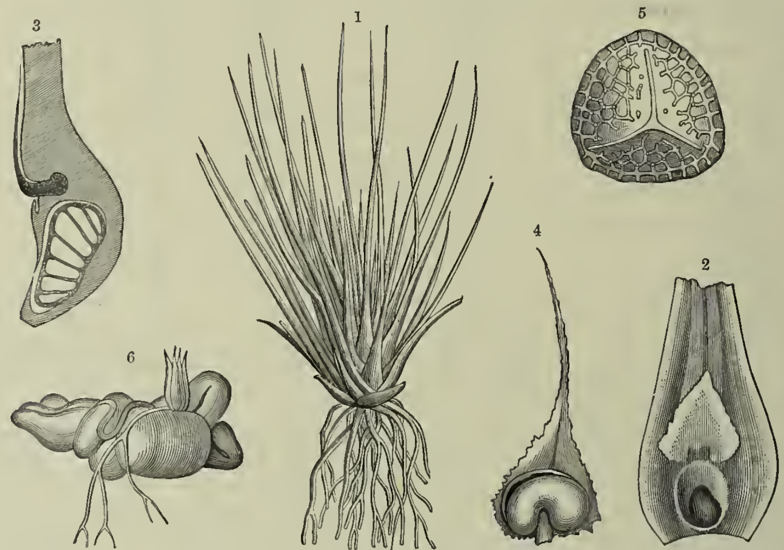


Fig. 405.—Lycopodiales.

1 *Isoëtes lacustris.* 2 Expanded base of leaf showing the sporangium immersed in its socket and partly hidden by the velum and the ligule above. 3 Longitudinal section of base of leaf showing the strands crossing the sporangium and the insertion of the ligule. 4 Leaf from the cone of *Lycopodium clavatum* showing the kidney-shaped sporangium. 5 A single spore of *L. clavatum.* 6 Prothallium of *L. annotinum* with young plant attached. 1 natural size; 2, 3, 4, 6 × 10; 5 × 100. (After Luerssen.)

Sigillariaceæ.—Another family which flourished in carboniferous times. Like the Lepidodendraceæ, their stems are gigantic, thickened and scarred; they were also heterosporous. The marks on the stems are not rhomboidal, but shield-like, and they stand in vertical rows. The curious branching remains named *Stigmaria* constitute the root (or rhizome) of *Sigillaria.*

Isoëtaceæ.—Is a small family of aquatic mode of life, containing the single genus *Isoëtes,* which is represented by some 50 species in various portions of the globe. Unlike the other members of the alliance Lycopodiales, *Isoëtes* possesses an abbreviated stem, bearing a tuft of lance-like leaves. The common British species *Isoëtes lacustris* may serve as type of the genus (fig. 405 1). It grows in quantity in the mud at the bottom of upland tarns and lakes in the northern parts of the country, and is attached by delicate roots which repeatedly fork. The very short

stem is furrowed on two sides, and from these furrows arise the roots. On rare occasions it is branched. From this stem arise numerous pointed leaves, which are slightly expanded below. Each leaf bears a sporangium, immersed in a socket on its upper surface (fig. 405 [2]), and partly covering the sporangium a membrane, the velum. Immediately above the sporangium is the ligule, a little tongue-like emergence of unknown function (figs. 405 [2] and 405 [3]). Macrosporangia, containing several large macrospores, are generally found on the outer leaves, and microsporangia, with very numerous microspores, on the inner ones. The sporangia are crossed by strands of cells (*cf.* fig. 405 [3]), termed trabeculæ, but these do not partition them into chambers. The germination of the spores presents certain resemblances to the same event in *Selaginella*, but it cannot be followed out in detail here.

An interesting feature in the structure of *Isoëtes* is the existence of a cambium-like zone in the stem just outside the central bundle-cylinder. This adds new tissue, both towards the inside and outside, but most abundantly towards the outside. This latter secondary cortex is parenchymatous, but in time it becomes corky. To its formation is due the curious form of the stem.

Though many species of *Isoëtes* live below water, others are terrestrial or semi-aquatic in habit. *I. lacustris*, as it grows at the bottom of a mountain tarn, is very similar in general appearance to two flowering-plants which affect the same situation, viz., *Lobelia Dortmanni* and *Littorella lacustris*; a closer inspection, however, will readily distinguish it.

Phylum IV.—PHANEROGAMIA, Flowering Plants

The general characters of Flowering Plants have been so fully dealt with in previous sections of this work that little more is needful here beyond a bare outline of the classification of their divisions and alliances.

The Phanerogamia are characterized by the production of seeds. The macrosporangia of heterosporous Archegoniatæ are here represented by ovules, the macrospores by embryo-sacs, and the microspores by pollen-grains. The macrospore (embryo-sac) remains inside its sporangium (ovule), and here produces the reduced female prothallium (endosperm), which never has an independent existence. An egg-cell is formed within the embryo-sac, and this is fertilized by the pollen-tube which has arisen from a pollen-grain lodged upon a suitable receptive surface in the vicinity of the ovule. Ultimately, after the embryo has attained a certain differentiation, the whole macrosporangium, with contained embryo and food-material, comes away, and is known as the seed.

The oophyte or prothallial generation is thus suppressed as an independent stage in the life-cycle. The sporophyte, on the other hand, attains to a markedly more complex development than in the groups already treated. Fertilization of archegonia on free-growing prothallia by swimming spermatozoids is here replaced by a direct penetration of pollen-tubes to the ovules. To the "flower" also new duties are

allotted. In the Pteridophytes, fertile "cones" are frequently met with. They are assemblages of leaves bearing sporangia, and with the shedding of the spores accomplish their function. But in the Phanerogams it is not so. The stamens, having shed their pollen-grains (microspores), truly are done with. But the carpels which bear the ovules persist *in situ* until the ripening of the seed. And in the vast majority of Phanerogams, structures accessory to the stamens and carpels have become associated with the flower. These, forming the perianth, promote the transfer of pollen by attracting insects to the flowers in the innumerable ways already fully indicated in this volume. A minority of species depend on wind, and are destitute of attractive perianths. It is worthy of passing notice that wind-pollinated plants, though relatively few in species, are well represented in number of individuals in the various Floras of the globe. It is sufficient to instance the Conifers, Grasses and Sedges, Palms, Amentaceæ, and Urticaceæ.

The phylum Phanerogamia is divided into two sub-phyla, Gymnospermæ and Angiospermæ, which differ technically in that in the former the ovules are exposed on scales and receive the pollen-grains direct into the micropyle, whilst in the latter the ovules are borne in closed chambers, the ovaries, and the pollen is received on a special organ, the stigma

Sub-phylum A.—GYMNOSPERMÆ.

The pollen is received direct upon the nucellus of the ovule, whence the pollen-tube penetrates to the egg-cell. The embryo-sac (macrospore) is filled with the endosperm (prothallium) which bears archegonia sunk in its substance at that end which is directed towards the micropyle. In almost all cases the archegonia possess neck- and canal-cells in addition to the egg.

The phenomena accompanying fertilization and seed-production in the Gymnospermæ having been described at pp. 418 and 437, brief statements of the general external characters alone are given below.

The Gymnospermæ are divided into 3 Classes: Cycadales, Coniferæ, Gnetales.

Class I.—CYCADALES, Cycads.

Alliance XXVI.

Family: *Cycadaceæ.*

In habit the Cycads generally resemble the Tree-Ferns and Palms. They possess for the most part unbranched columnar stems terminating in a crown of large pinnate leaves. The surface of the stem is scarred with the bases of the fallen leaves, and recalls in appearance that of the fossil Lepidodendrons (*cf.* p. 716). In height Cycads do not exceed about 12 metres, and usually they do not attain even these dimensions. The flowers take the form of cones of closely aggregated scales, which vary in number from 30 to 600. The cones are respectively male and female, and

Fig. 406.—A group of *Cycas revoluta*. (From a photograph.)

are produced in close proximity to the apex of the plant, and sometimes (as in the female cone of *Cycas*) are actually terminal in position. The scales (stamens) of the male cones are usually boat- or shield-shaped, and bear very numerous pollen-sacs on their under surfaces, often aggregated into little groups or sori. The female cones are generally more massive than the male, and their scales (carpels) are shield-like or scale-like in form. In *Cycas revoluta* (*cf.* fig. 208 [7], p. 74) the carpels more nearly resemble the foliage-leaves, and the ovules are borne in the position of leaflets. In other genera the number of ovules is restricted to two. Pollination is accomplished by the wind, and the ovule as it ripens develops a hard shell enveloped in a fleshy coat. The seed thus exhibits the superficial characters of a drupe (*cf.* p. 428).

Cycads are restricted to the warmer regions of the globe, and are especially characteristic of the Floras of Australia (*Macrozamia, Bowenia, Cycas*) and Central America (*Zamia, Ceratozamia, Dioon*). There are nearly 80 species, belonging to 9 genera, and they have mostly a somewhat restricted distribution. Fossil remains, from the Cretaceous onwards, are abundant, and show that in former times the Cycads formed a much more important constituent of the vegetation than at the present day.

A living collection of these interesting plants is cultivated in the Palm-house in Kew Gardens; it is exceedingly rich in forms, all the genera, and a large number of the species being represented.

Class II.—CONIFERÆ.

Alliance XXVII.

Families: *Araucariaceæ, Abietineæ, Taxodieæ, Cupressineæ, Taxaceæ.*

The Coniferæ, which include the various Pines, Firs, Junipers, Cypresses, and Yews, have characteristically branched stems. The leaves are usually linear and needle-like or scaly, rarely possessing an expanded lamina. The flowers are unisexual, and occasionally the sexes are on different individuals. In by far the larger number of Conifers the flowers are cone-like, *i.e.* aggregates of scales set upon a central axis and bearing respectively ovules and pollen-sacs. The stems of Conifers thicken up in the manner characteristic of Dicotyledons, but the secondary wood is composed entirely of tracheides (fibre-shaped elements), with peculiar bordered pits (*cf.* vol. i. figs. 10 [1, 2, 3], p. 45); vessels are absent from it. In a great number of forms resin-ducts are present.

The families above given fall into two groups. The first of these includes the Araucariaceæ, Abietineæ, Taxodieæ, and Cupressineæ, and is characterized by the female flowers being cone-like. In the Taxaceæ, on the other hand, the female flowers are rarely in cones.

Araucariaceæ.—This group is familiar to everyone in the widely cultivated Chili Pine or "Monkey-puzzle" (*Araucaria imbricata*). The cones are made up of scales spirally arranged, and the ovules are solitary on the scales of the female

cones. The only other genus is *Agathis* (*Dammara*). These two genera include 14 species, distributed in the Southern Hemisphere only.

Abietineæ.—This family includes the majority of familiar Conifers of the Northern Hemisphere. They are distinguished by the fact that the scales of the female cones are divided into an upper ovule-bearing scale (the *ovuliferous scale*) and a lower subtending *bract scale.* The ovules are borne in pairs on the former,

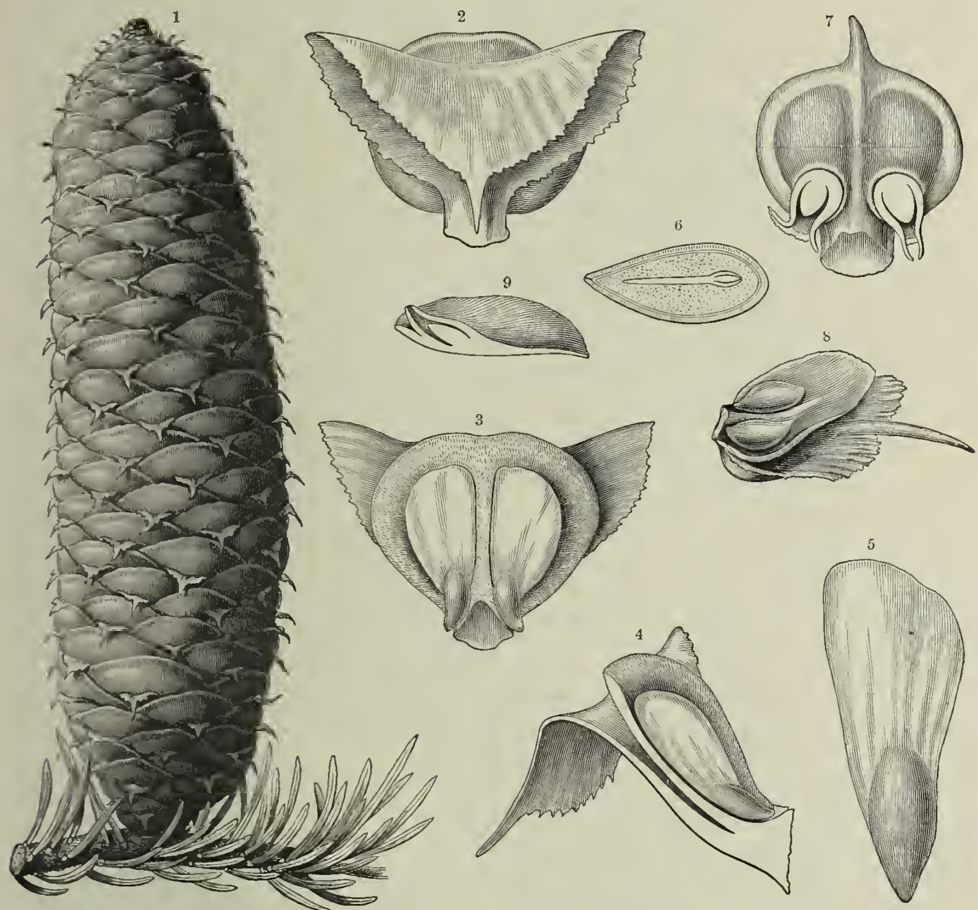


Fig. 407.—Female Cone and Scales in Abietineæ.

[1] Cone of the Silver Fir (*Abies pectinata*). [2] Bract scale and ovuliferous scale of the same seen from the outside (the bract scale is pointed). [3] Ovuliferous scale of same seen from above, showing the two winged seeds, and the bract scale behind. [4] Longitudinal section of bract and ovuliferous scales, showing a seed *in situ* upon the latter. [5] A winged seed of the same. [6] Longitudinal section of the seed. [7] Ovuliferous scale of the Scotch Pine (*Pinus sylvestris*) seen from above; it bears two ovules. [8] Single ovuliferous scale of Larch (*Larix europæa*) showing two ovules on its surface and bract scale (with bristle) below it. [9] Longitudinal section of the ovuliferous scale of the Larch. [1] nat. size; the other figs. enlarged.

and on ripening into seeds are provided with membraneous wings in most cases. The relations of the parts of the scales and of the ovules are fully illustrated in the accompanying fig. 407. The pollen-grains also are characteristic, being in nearly all cases provided with two sac-like appendages which promote transit by wind (*cf.* fig. 217 [8], p. 98).

Included here are the Pine (*Pinus*), Cedar (*Cedrus*), Larch (*Larix*), and the

various kinds of Firs (*Abies* and *Picea*). All have needle leaves, but variously arranged. In *Pinus* the needles are borne in tufts of two (figs. 408 [4] and 408 [5]) or three or five. The tufts are really short branches which arise in the axils of relatively

Fig. 408.—Mountain Pine (*Pinus Pumilio*).

[1] A single polliniferous scale (stamen) seen from above. [2] Three polliniferous scales, one above the other, seen from the side. The pollen falling from each anther alights on the upper surface of the stamen next below. [3] Two spikes of polliniferous scales. [4] Branch with apical group of staminal flowers from which pollen is being discharged. [5] Female flower. [1], [2] ×10; [3]×8; [5]×2; [4] natural size.

inconspicuous scales (*cf.* fig. 408 [5]) and though these branches are produced plentifully, permanent long branches arise only at the yearly limits of growth. The

Fig. 409.—The Scotch Pine (*Pinus sylvestris*).

Fig. 410.—The Arolla Pine (*Pinus Cembra*).

Pines may conveniently be divided into 2- and 3-leaved forms on the one hand, and 5-leaved on the other. The former agree in possessing cones of the type shown in fig. 337[2], p. 443, in which the ends of the ovuliferous scales visible at the surface of the cone are pyramidal, whilst the 5-leaved forms are without these terminal pyramids. Among the 2-leaved Pines (20 species) are included the Scotch Pine (*P. sylvestris*, fig. 409), the Stone Pine (*P. Pinea*), the Mountain Pine (*P. humilis* or *montana*, Plate X., and fig. 135, vol. i. p. 549), the Corsican and Aleppo or Shore Pines (*P. Laricio* and *P. halepensis*), and many others. Of the 16 species of 3-leaved Pines the majority are North American and Oriental. The Himalayan *P. longifolia* has needles nearly half a metre long, and the Californian *P. Coulteri* cones attaining a like length.

The 5-leaved forms include about 35 species, of which the beautiful Arolla Pine (*P. Cembra*, fig. 410) is a European, and the Weymouth Pine (*P. Strobus*) a North American example.

The genus *Cedrus* is represented by 3 forms, the Cedar of Lebanon (*C. Libani*), common in Asia Minor, the Deodar (*C. Deodara*) of the Himalayas, and the Atlas Cedar (*C. atlantica*). Some authorities regard these as but varieties of one species.

The Larch (*Larix*, *cf.* fig. 337[1], p. 443, and fig. 354, p. 483) bears its needles, which are deciduous, in tufts. The Firs which comprise the genera *Abies*, *Picea*, and *Tsuga*, differ from the Pines, &c., in that the leaves are borne directly upon the elongating branches. *Abies*, typified by the Silver Fir (*Abies pectinata*, *cf.* fig. 177, vol. i. p. 717), has erect cones (*cf.* fig. 407[1], p. 721), with conspicuous bract and ovuliferous scales; on ripening, the scales disarticulate from the axis of the cone. *Picea*, typified by the Spruce Fir (*Abies excelsa*, *cf.* fig. 105, vol. i. p. 415), has pendulous cones, with persistent scales, and, as a rule, the bract scale remains relatively short. *Tsuga Douglasii*, the Douglas Fir, and the Hemlock Firs are in certain respects intermediate between the Silver and Spruce Firs.

In all there are 120 species of Abietineæ distributed over the cooler parts of the Northern Hemisphere.

Taxodieæ.—Are characterized by bearing more than two ovules on the scales of their cones. They include the two big *Sequoia*-species of North America, *S. gigantea*, the Wellingtonia or Californian Mammoth Tree, and *S. sempervirens*, the Red-wood, both of which attain to huge dimensions. *Taxodium distichum*, the so-called Deciduous Cypress, interesting on account of the curious knee-like roots which it produces above ground, *Cryptomeria japonica*, and *Sciadopithys verticillata*, the Umbrella Pine of Japan, all cultivated in this country as ornamental trees, are members of this group, which comprehends some 12 species in all.

Cupressineæ.—Are characterized by the fact that their cones have their scales in whorls, not spirals (*cf.* figs. 336[6] and 336[7] on p. 442, and figs. 337[3, 4, 5,] p. 443). They include about 80 species, amongst them the Cypress (*Cupressus*), Arbor Vitæ (*Thuja*), *Juniperus*, and other ornamental genera.

Taxaceæ.—Have generally few scales in their female cones, and sometimes, as in Taxus, the Yew (*cf.* fig. 234, p. 145, and figs. 336[1, 2, 3, 4, 5,] p. 442), the ovule is

terminal on a little shoot of its own. The seeds in this group are frequently embedded in a fleshy investment (often arillar in nature). Besides the Yews, there are included several peculiar Australasian forms, and the Maidenhair Tree, *Gingko biloba* (*cf.* fig. 337 [7], p. 443). There are about 70 species of Taxaceæ.

Class III.—GNETALES.

Alliance XXVIII.

Family: *Gnetaceæ.*

This family which includes three very dissimilar genera, *Ephedra*, *Gnetum*, and *Welwitschia*, is by no means easy to define. In habit they are all of them quite unlike the members of the two preceding classes, but yet they fall under the sub-phylum Gymnospermæ in view of the fact that the pollen-grain has direct access to the nucellus of the ovule and from the resemblance (rather remote) which their ovules and embryogeny presents to other Gymnosperms. They agree amongst themselves in possessing flowers with perianths, vessels in their wood, and in the absence of resin-ducts from their tissues.

Ephedra is a good example of a switch-plant, having jointed assimilating shoots with little scale-like leaves at the nodes, as in *Casuarina* or *Equisetum*. The flowers which are borne in little clusters, are small and unisexual. The male flower consists of a central columnar stamen bearing 2–8 anthers and inclosed in a 2-leaved perianth. The female flower has an ovule with one integument and a little perianth. As the seed ripens the bracts around the flower become red and fleshy. There are some 20 species scattered over the warmer regions of the globe, including the Himalayas, Mediterranean, and Mexico.

Gnetum occurs as a liane or erect tree, and has expanded leaves like a Dicotyledon, in decussating pairs. The flowers occur in clustered, catkin-like spikes, on which they are arranged in whorls. The male flowers are very like those of *Ephedra*, the female have a central ovule with 2 integuments inclosed in a flask-shaped perianth. On ripening, the perianth becomes fleshy, and the outer integument of the ovule hardens to a stone. There are 15 species, distributed in the tropics.

Welwitschia mirabilis is a plant altogether unique. Discovered some thirty-five years ago by the botanical explorer Welwitsch, it has formed the subject of a classical monograph by Hooker. It occurs in the desert regions of West Tropical Africa (Angola, Damaraland, &c.). The stem is dwarf and top-shaped (*cf.* fig. 411), and may attain more than a metre in diameter. The summit of the plant never reaches far above the surface, and it bears two huge leathery leaves which sprawl on the sand on either hand. Actually 4 leaves are produced, the 2 cotyledons, which fall away whilst the plant is still quite young, and an additional pair placed at right angles to the cotyledons and persisting throughout the life of the plant. These 2 leaves grow continually at the base whilst their apical regions become

Fig. 411.—*Welwitschia mirabilis* in its natural surroundings (from a sketch by its discoverer).

tattered and broken. *Welwitschia*, once established, does not increase much in length but continually in thickness. From the edge of its disc, in the leaf-axils, arise branches which bear cones (*cf.* fig. 411). The male cones are small, and in the axils of their scales occur flowers consisting of 6 stamens united together into a sheath and surrounding a central structure which resembles an ovary, and contains a single ovule, which is, however, so far as is known, always abortive. This ovary-like structure is provided with a trumpet-like "stigma", and the occurrence of this remarkable structure in the male flowers points to the fact that the ancestors of this plant possessed hermaphrodite flowers. The fertile female flowers occur in the axils of the scales of other much larger cones, which become bright red in colour. Each flower consists of a perianth containing an ovule with 2 integuments, but although the inner of these integuments is very long, there is no stigma-like structure as in the male flower, and the pollen-grain reaches the nucellus. The developmental history of the ovule and embryo is exceedingly peculiar—as it is also in *Gnetum*—but we cannot enter into these matters here.

Sub-phylum B.—**ANGIOSPERMÆ.**

Ovules contained in closed ovaries. Pollen received on a specialized portion of the carpel known as the stigma, and fertilization achieved by means of pollen-tubes which penetrate hence to the ovule.

Angiosperms fall naturally into two classes, *Monocotyledones* and *Dicotyledones.*

Class I.—MONOCOTYLEDONES.

Includes Flowering Plants whose flowers typically have their parts arranged in whorls of three, embryos with one cotyledon, vascular bundles scattered through the stem and not thickened by a cambium, leaves usually parallel-veined.

The Monocotyledones may be divided into 6 alliances:—Liliifloræ, Scitamineæ, Gynandræ, Fluviales, Spadicifloræ, and Glumifloræ.

Alliance XXIX.—**Liliifloræ.**

Families: *Juncaceæ, Liliaceæ, Amaryllidaceæ, Iridaceæ, Dioscoreaceæ, Bromeliaceæ, Commelynaceæ, Pontederiaceæ.*

In this alliance the flowers are actinomorphic, and their parts arranged in whorls of three, *i.e.* two whorls constituting the perianth, two (or one) whorls of stamens, and a whorl of three carpels united together. This condition may be briefly represented by the following formula:—P 3 + 3, A 3 + 3, G (3), in which P, A, and G stand for perianth, andrœcium, and gynæceum respectively. The bracket inclosing the number of carpels indicates that they are united (*syncarpous*). The ovary is 3-celled, and may be either superior or inferior; the seeds contain endosperm.

The Liliifloræ are for the most part herbs with perennial underground bulbs, corms, and rhizomes. In relatively few cases is a permanent above-ground system

Fig. 412.—Liliifloræ.

[1] *Gagea lutea.* [2] *Galanthus nivalis.* [3] *Leucojum vernum.* [4] *Colchicum autumnale,* in flower and in fruit. [5] Section of capsule of *Colchicum.* [6] *Bulbocodium.* [7] *Convallaria majalis.* [8] Stigmas and stamens of an Iris.

produced. With the exception of the *Juncaceæ* the flowers are conspicuous and brightly coloured.

Juncaceæ.—Plants of grass-like habit with inconspicuous glumaceous perianth, six stamens, and superior ovary, which is 3- or 1-celled. Pollination by wind. Pollen-grains united into tetrads. Two well-known genera represented in this country are *Juncus* (with about 190 species), which includes the Rushes, and *Luzula*, the Woodrush. In all there are some 250 species of Juncaceæ.

Liliaceæ.—Herbaceous plants with bulbs, rhizomes, and corms, conspicuous

Fig. 413.—*Asphodelus ramosus* at Paestum (Southern Italy).

flowers with petaloid perianth, stamens 6, carpels 3, united, ovary 3-celled superior. Pollination by insects. Fruits are capsules or berries.

A number of tribes may be distinguished: (1) *Colchicaceæ* having usually extrorse anthers, septicidal capsules, and distinct styles. They include *Veratrum*, *Colchicum autumnale*, the Meadow Saffron (fig. 412 [4]), which sends up its flowers in autumn, its leaves and ripening capsule next spring. *Bulbocodium* (fig. 412 [6]) is frequent in cultivation. The Bog Asphodel (*Narthecium*) also belongs to this tribe. (2) *Asphodeloideæ* include forms generally with rhizomes, rarely bulbs; anthers introrse, fruits capsular. Examples are *Asphodelus*, e.g. *A. ramosus* (fig. 413), which covers considerable tracts of country in southern Europe, forming regular plantations, and was supposed to carpet the Elysian fields; *Paradisea*


Eucalyptus amygdalina
Xanthorrhoea hastilis

EUCALYPTUS GROVE AND GRASS-TREES IN AUSTRALIA.

Printed from the originals by the BIBLIOGRAPHISCHES INSTITUT, Leipzig.

Liliastrum, a beautiful alpine plant; *Hemerocallis*, the Day Lily; *Phormium tenax*, the New Zealand Flax (fig. 414), the leaves of which yield a valuable fibre; *Kniphofia*, whose dense spikes resemble a red-hot poker, cultivated in gardens; the Aloes and their allies, chiefly African, with a permanent aërial branch-system; finally, the Australian Grass-trees (e.g. *Xanthorrhœa hastilis*, shown in Plate XVI.), often a conspicuous feature in the landscape, and with its long spicate inflorescence sometimes attaining a height of 3 metres or more. This plant yields a valuable gum. (3) *Allioideæ*, usually bulbous, and having flowers

Fig. 414.—*Phormium tenax*, the New Zealand flax.

in umbels. They include the Onion tribe (*Allium*, *cf.* fig. 311, p. 386), of which *A. cepa* the Onion, *A. porrum* the Leek, *A. ascalonicum* the Shallot, *A. sativum* the Garlic, *A. schœnoprasum* the Chive, and *A. scorodoprasum* the Rocambole, are cultivated. *Gagea* (fig. 412 [1]) also belongs to this group. (4) *Lilioideæ* have bulbs, anthers introrse, and loculicidal capsules. Styles generally united. They include numerous familiar and beautiful plants: *Lilium* (45 species), *Fritillaria* (40 species), *Erythronium* the Dog-tooth Violet, *Tulipa* (50 species), *Scilla*, *Hyacinthus*, *Ornithogalum* the Star of Bethlehem, *Muscari*, &c. (5) *Dracænoideæ* is an interesting tribe, as it includes the Yuccas and Dracænas, which possess a permanent aërial system, which exhibits what is very exceptional amongst Monocotyledons, a secondary thickening of the stem. *Dracæna Draco*, the Dragon-tree of

the Canaries, attains huge dimensions and a great age, and is altogether peculiar among this type of vegetation. The flowers of *Yucca* (fig. 415) are represented on p. 157, and its pollination described. (5) *Convallariaceæ* have rhizomes and berries.

Fig. 415.—*Yucca gloriosa* (from a photograph).

They include *Convallaria majalis* the Lily of the Valley (fig. 412 [7]), *Polygonatum, Aspidistra, Asparagus, Trillium, Ruscus* (vol. i. p. 333), and Herb Paris (*Paris quadrifolia*)—the last-named with the parts of its flowers in fours. (6) *Smilacoideæ*, which include climbers with net-veined leaves, e.g. *Smilax*.

Fig. 416.—*Æchmea paniculata* (after Baillon).

Amaryllidaceae.—Resemble Liliaceae, but have inferior ovaries, and in many cases a corona to the perianth. They include the Snowdrop (*Galanthus nivalis*, fig. 412 [2]), Snowflake (*Leucojum vernum*, fig. 412 [3]), *Clivia, Amaryllis, Crinum, Narcissus* (with well-marked corona, fig. 248, p. 177); also, *Agave* and *Fourcroya* (*cf.* vol. i. p. 657).

Iridaceæ.—Resemble Amaryllidaceae, except that they have three stamens only, with extrorse dehiscence. The stigmas are commonly very conspicuously developed. They include the Iris (figs. 412 [8] and 265), *Crocus* (fig. 223, p. 113), *Gladiolus*, the flowers of the last-named being slightly zygomorphic, and many others.

Bromeliaceæ.—Possess distinct calyx and corolla. Ovary superior or inferior; fruit a berry or capsule. The family is tropical American, and very many of its members are epiphytes, showing interesting adaptations to this particular mode of life. The accompanying fig. 416 of the Peruvian *Æchmea paniculata* gives a good idea of their mode of growth, with rosette of tough, leathery, sword-shaped leaves and dense, terminal inflorescence. Not infrequently the bracts which accompany the flowers are very brightly coloured. Two of the chief tribes of this family are *Tillandsieæ*, with capsular fruits, hairy seeds, and entire leaves; and *Bromelieæ*, with baccate fruits and toothed leaves (*cf.* fig. 416). The former includes the rather aberrant *Tillandsia usneoides* (*cf.* vol. i. p. 614), a widely-distributed American epiphyte which covers trees much in the same way as does the Lichen *Usnea barbata* in temperate zones. To the Bromelieæ belong numerous forms, including the *Æchmea* figured here, and the Pine-apple (*Ananassa sativa*), the various portions of the fruiting-spikes of which become entirely succulent and confluent, forming the collective fruits referred to on p. 436.

The family includes about 400, and the whole alliance over 4000 species.

Alliance XXX.—*Scitamineæ.*

Families: *Musaceæ, Zingiberaceæ, Cannaceæ, Marantaceæ.*

This alliance includes tropical plants with rhizomes and large conspicuous leaves. In the flowers there is more or less reduction of the andrœcium, often combined with a production of petaloid staminodes. The ovary is inferior, and usually 3-celled, and the seeds, which are often inclosed in arils, have perisperm. The flowers are zygomorphic, or destitute of any sort of symmetry. As a whole this alliance is one of the most remarkable amongst the Monocotyledons.

Musaceæ.—The flowers of this family agree most nearly with those of typical Monocotyledons. Of the six stamens one only is absent or developed as a staminode. The flowers are zygomorphic. They include *Musa sapientum* (the Banana) and *M. paradisiaca* (the Plantain), widely cultivated for their fruits; *Strelitzia*, a remarkable South African genus, and *Ravenala Madagascariensis*, the Traveller's Tree, so named from the water which accumulates in the excavated sheaths of the leaf-stalks. This plant attains a height of 10 metres, and has a remarkable appearance (*cf.* fig. 417) owing to the fact that its huge leaves (amongst the largest in the

Fig. 417.—The Traveller's Tree (*Ravenala Madagascariensis*). After a drawing by Selleny.

vegetable kingdom) are borne in one plane. The fruits are large capsules, and the seeds are inclosed in arils with blue metallic lustre.

Zingiberaceæ.—One stamen, the posterior of the inner whorl, alone is fertile. The two others of this whorl are joined together to form a petaloid structure—the labellum. Here are included the Ginger (*Zingiber*), *Alpinia* (fig. 283 [1], p. 289), and *Hedychium*, cultivated for the beauty of its flowers; also *Globba* and *Mantisia* (the Opera Girl) with flowers altogether remarkable; *M. saltatoria* presents some resemblance to a ballet-dancer, hence the name.

Cannaceæ.—Flowers altogether asymmetrical. The fertile stamen possesses only a half-anther and several petaloid staminodes are present forming the most conspicuous portion of the flower. *Canna indica,* the Indian-shot, and other species are much cultivated, and have given rise to numerous brilliantly-coloured hybrids.

Marantaceæ.—Have asymmetrical flowers and a fertile half-stamen only. The other stamens are modified into peculiar staminodes, and the family is nearly allied to Cannaceæ. Arrowroot is obtained from the rhizomes of species of Maranta.

The Scitamineæ includes about 600 species.

Alliance XXXI.—**Gynandræ.**

Families: *Orchidaceæ, Burmanniaceæ.*

Flowers with petaloid perianth and inferior ovary. The stamens reduced to one, two, or three, and generally united with the gynæceum to form a column (hence the name Gynandræ). The fruits are capsules, and the seeds exceedingly small and numerous.

Orchidaceæ.—After the Compositæ, the largest family of flowering plants, numbering some eight thousand or more species. Its members are chiefly tropical epiphytes, and their mode of life has received frequent mention in vol. i. Very characteristic of the Orchid flower is the median petal, developed as a labellum (*cf.* fig. 258 [1] p. 227, and fig. 268 [2] p. 255). The family may be divided into two divisions according to the number of stamens present.

Division 1. *Diandræ.*—Having usually two polliniferous stamens and a large and conspicuous staminode (which corresponds to the single fertile stamen of the Monandræ). The Lady's Slipper (*Cypripedium, cf.* figs. 267 [1] and 267 [2], p. 249, and description on p. 253) is the best-known representative of this division. A little group of plants, the Apostasiaceæ, is also included here. To it belongs *Neuwiedia,* with 3 fertile stamens (*i.e.* the two found in *Cypripedium* and the one which is represented by the staminode).

Division 2. *Monandræ.*—Includes the greater portion of the family, with one stamen only united with the gynæceum into the column and producing pollen in masses (pollen-masses). The single stamen is inserted above the stigmatic surface, from which it is separated by the rostellum, and is on that side of it which is away from the labellum, the usual alighting place for insects. The structure of the monandrous Orchid flower having been fully described and figured (pp. 253–257),

repetition is not needful here. The Monandræ may be divided into four tribes, the *Ophrydeæ*, *Neottieæ*, *Vandeæ*, and *Epidendreæ*.

The *Ophrydeæ* include most of the British and European Orchids, which are not

Fig. 418.—*Angræcum eburneum* epiphytic on a tree-trunk (Madagascar).

epiphytes but terrestrial, with swollen tuberous roots, including *Orchis*, *Ophrys*, *Gymnadenia*, *Habenaria*, and the South African *Disa*.

The *Neottieæ* also include some European forms, *Cephalanthera*, *Listera ovata* (the Twayblade), &c., and a series of colourless forms of saprophytic habit, which are destitute of foliage, including *Epipogium aphyllum* (fig. 257 [10], p. 226), *Neottia*

Nidus-avis (the Bird's Nest Orchid), and *Corallorhiza* (the Coral-root). To this tribe belongs the climbing Vanilla-orchid (*Vanilla planifolia*) the capsules of which yield the spice.

To the *Vandeæ* and *Epidendreæ* belong the numerous tropical epiphytes of which many genera are widely cultivated in greenhouses, such as *Lælia*, *Epidendrum*, *Cattleya*, *Masdevallia*, *Phajus*, *Catasetum*, (figs. 275 [1, 2, 3, 4, 5, 6, 7,] p. 269), *Stanhopea* (Plate XIII.), *Phalænopsis* (fig. 258 [1], p. 227), *Odontoglossum*, (Plate XIII.), *Dendrobium* (fig. 275 [8]), *Oncidium* (Plate XIII.), *Angræcum* (fig. 418), and many others besides (vol. i. Plate III.).

To give any idea of the enormous varieties of floral structure met with among the Orchids would require a whole volume. In this family of all others do we find adaptations to insect visits carried out on a gigantic scale, and in not a few cases mechanisms of singular beauty and delicacy. For full details Darwin's *Fertilization of Orchids* should be consulted.

Burmanniaceæ.—A small family of some 60 species, largely represented in Borneo and New Guinea, is of interest, as it seems to connect the highly specialized Orchidaceæ with more typical Monocotyledons like Amaryllidaceæ. They have curious flowers, with three or six stamens, and several of them are saprophytic.

Alliance XXXII.—**Fluviales.**

Families: *Potamogetaceæ*, *Naiadaceæ*, *Aponogetaceæ*, *Juncaginaceæ*, *Alismaceæ*, *Butomaceæ*, *Hydrocharidaceæ*.

This alliance includes a large number of aquatic forms, some with narrow, some with broad leaves. The gynæceum is superior, except in the Hydrocharitaceæ. The stamens and carpels show a tendency to an increased number as compared with typical Monocotyledons. On the other hand, many forms with reduced flowers occur. Endosperm is generally absent.

Potamogetaceæ.—Include chiefly submerged forms, some of which raise their inflorescences above the water-level, and are wind-pollinated (*Potamogeton*, fig. 419), whilst the others, including the Sea-grass (*Zostera marina*), *Zannichellia*, &c., are pollinated below the water. *Potamogeton* (Pondweed) is a large genus of some 50 species, met with in fresh and brackish water; *Zostera* grows on sandy shores between tide-levels, often forming extensive belts. The embryos in this family are peculiar. They consist of a much-thickened hypocotyl with a relatively small cotyledon inserted upon it. They are termed macropodous.

There are about 74 species of Potamogetaceæ.

Aponogetaceæ.—Contains two interesting genera, *Aponogeton* and *Ouvirandra*. The plant is submerged, and raises a spicate inflorescence (often forked) above the water. The flowers are imbedded in the spike, and consist of some 6 stamens and 3 free carpels, and a small number of perianth-segments. *Aponogeton distachus* is often cultivated in this country on account of its beautiful white flower-spikes. *Ouvirandra fenestralis* is the Lattice-leaf plant of Madagascar.

There are 15 species in all.

Alismaceæ.—Possess a 6-leaved perianth, and stamens with tendency to increase by division; carpels numerous. Here are included *Alisma Plantago,* the Water Plantain, and *Sagittaria sagittifolia,* the Arrowhead.

There are about 50 species.

Butomaceæ.—Includes *Butomus umbellatus,* the Flowering Rush, interesting from the fact that it bears ovules all over the internal surface of its carpels.

Fig. 419.—Curled Pondweed (*Patamogeton crispus*).

Hydrocharidaceæ.—Is distinguished from the foregoing families in that it includes submerged forms with inferior ovaries. The flowers are frequently unisexual, and in one form (*Halophila*) are pollinated under water, as in so many of the Potamogetaceæ. To this family belong *Vallisneria* (see fig. 155, vol. i. p. 667 and fig. 227, p. 132), *Elodea,* the American Water-weed (alluded to on p. 457), *Lagarosiphon* and *Enalus* (p. 133), *Stratiotes aloides,* the Water-soldier (vol. i. p. 552) and *Hydrocharis Morsus-ranæ,* the Frog-bit, with expanded floating leaves.

Contains about 60 species.

Alliance XXXIII.—**Spadicifloræ.**

Families: *Palmaceæ, Aroideæ.*

Monocotyledons with small and usually unisexual flowers crowded on spikes or spadices, and inclosed in one or more conspicuous sheaths, the spathes. The ovaries are superior.

This alliance may be contrasted with the group Compositæ of Dicotyledons in which also the individual flowers are merged in dense crowded inflorescences which superficially resemble single flowers (cf. *Arum* and *Chrysanthemum*).

Palmaceæ.—Include plants with cylindrical, woody stems and tough fan-shaped or feather-like leaves of large dimensions having a plaited vernation. The flowers are borne in branched, fleshy spikes often inclosed in large sheathing leaves; they are hermaphrodite or unisexual and actinomorphic; the parts are arranged in threes, and are inconspicuous. The gynæceum consists of three carpels, each containing one seed. Stamens six, pollen dust-like. Fruits are berries, drupes, and nuts, and contain three, or by suppression, one seed. The endosperm is copious, and generally hard and stony. The majority of Palms possess upright, columnar caudices surmounted by a huge tuft of crowded leaves (*cf.* vol. i. p. 289, and Pl. VIII.). In several species the caudex attains a height of 30 metres, and in one (*Ceroxylon andicola*) 57 metres. The Climbing Palms have slender branched stems, and by the aid of the hooks on their leaves mount to the summit of trees and stretch like lianes from crown to crown (*cf.* vol. i. pp. 363, 675, and 676). The stems of these Palms reach a length of 150–200 metres, and yield the rotang cane. The opposite figure shows the interior of a forest penetrated by Climbing Palms and two natives rolling the stems into a coil. Old Palm-stems are either smooth and show the scars of the fallen leaves, or they still bear the disintegrated fragments of former foliage-leaves. Others again are armed with spiny girdles and scales. The leaves are folded in bud and undivided, and as they unfold they split along the creases, and the blade is divided pinnately or like a fan; we may distinguish between the feather-leaved and fan-leaved Palms. Often in young Palms the leaf splits at the apex into two pointed lobes only, as in *Areca disticha*, represented the foreground of fig. 420. The dimensions of Palm-leaves and the gigantic inflorescence of the Talipot Palm (*Corypha umbraculifera*) have already been alluded to (*cf.* vol. i. pp. 287 and 745). In *Oreodoxa regia* the sheathing base of the leaf attains a length of 2 metres and a half. The fruits of many species (e.g. *Chamærops excelsa*) are borne in grape-like bunches; in others they attain to great size and weight. The Double Cocoa-nut, the fruit of *Lodoicea Sechellarum*, is prominent in this respect (*cf.* p. 452).

Most Palms are eminently tropical in their distribution. Some genera are met with throughout the tropics, others (e.g. *Mauritia, Oreodoxa,* and *Iriartea*) are confined to the New World; others again, as *Borassus* (*B. flabelliformis*, Pl. VIII.). *Raphia, Caryota,* and *Calamus* to the Old. *Chamærops humilis,* alone of the

Fig. 420.—Primeval forest in Ceylon with Climbing Palms (*Calamus*) and *Areca disticha* in foreground to the right. (Drawn from nature by v. Ransonnet.)

Palms is indigenous to Europe; *Ceroxylon andicola* is found in the Andes growing at a height of 270 metres. Fossil remains are found in the formations of the secondary and tertiary formations. The number of living species is about 1100.

Aroideæ.—Perennial plants with tubers, rhizomes, and climbing stems which

Fig. 421.—Aroids.

1 *Arum maculatum.* 2 Spadix of *A. maculatum*, the spathe removed. 3 Fruiting spike of same. 4 Inflorescence of *Colocasia antiquorum.* 5 Basal portion of this inflorescence with part of spathe removed. 6 Ovary of *Colocasia antiquorum.* 7 The same in longitudinal section. 8 Columnar andrœcium of same. 9 *Ariopsis peltata.* 2, 5, 9 nat. size; 1, 8, 4 reduced; 6, 7, 8 enlarged.

generally bear large foliage-leaves. The flowers are borne on unbranched, fleshy spadices which are inclosed in large, expanded spathes (*cf.* figs. 421[1, 4, 5, 9]); they are unisexual or hermaphrodite. The parts are inserted in whorls of 2 or 3; the perianth-members being inconspicuous and often absent. The andrœcium is very various. In *Colocasia antiquorum* (fig. 421[8]) it consists of a whorl of stamens

Fig 422.—*Raphidophora decursiva* climbing in a primeval forest of the tropical Himalayas (from a photograph)

Fig. 423.—Climbing Aroids (*Philodendron pertusum* and *P. Imbe*) with cord-like aërial roots.

united into a single abbreviated column. Endosperm is present in the seeds. The tribe *Pisteæ* includes floating plants with leaves arranged in rosettes and propagating vegetatively by means of stolons. The *Areæ*, of which the Arum (figs. 421 [1, 2, 3]) may be taken as a type, have subterranean tuberous stems, from which arise the leaves and spadices. Numerous representatives of other tribes, including *Ariopsis, Caladium, Dracontium,* and *Amorphophallus* have tubers. *Amorphophallus titanum,* the giant of this family, has a tuber 50 centimetres in diameter, and produces umbrella-like leaves on stalks 2–5 metres long and with segments in proportion. The inflorescence is a huge spadix some 2 metres high, encircled by a sheath of beautiful mottled green with purple lining and frilled edge. When this plant flowered at Kew in 1890 (for the first and as yet only time in captivity) it was one of the sensations of a London season. It is a native of Sumatra. A few species of *Montrichardia* (*M. linifera*) and *Philodendron* (*P. bipinnatifidum*) have erect cylindrical stems, whilst the Snake-root (*Calla palustris*) and Sweet Flag (*Acorus Calamus*) have creeping rhizomes. Many tropical Aroids belonging to the tribes Monstereæ and Pothoideæ climb up the stems of trees, fastening themselves by their aërial roots, and pass from crown to crown like lianes. The Himalayan *Raphidophora decursiva* (fig. 422) is an example of this type of growth. Many of these climbing Aroids send down pendent aërial roots into the humid air of the forest (fig. 423), and these not unfrequently reach the ground, take root, and become stretched taut.

The majority of Aroids are tropical, less than 10 per cent of the species being met with in temperate regions. *Acorus Calamus, Arum maculatum,* and *Calla palustris* reach the furthest north. The curious *Ariopsis peltata* (fig. 421 [9]) occurs in the Himalayas to a height of 1600 metres.

There are about 900 species of living Aroids.

The *Lemnaceæ* is a little family of reduced forms allied to Aroideæ. The flowers are unisexual, and consist of a stamen and a carpel respectively. They are floating, flattened forms, and include *Lemna* (the Duckweed), and *Wolffia,* which is destitute of roots.

Associated with the Spadicifloreæ are the Pandanaceæ, which include *Pandanus utilis,* the Screw Pine (*cf.* vol. i. fig. 186, p. 758); Cyclanthaceæ, climbing and palm-like; Sparganiaceæ and Typhaceæ, marsh plants, which include *Sparganium,* the Bur-reed, and *Typha,* the Bulrush.

Alliance XXXIV.—**Glumifloræ.**

Families: *Gramineæ* and *Cyperaceæ.*

This alliance, which includes some 6000 species, consists exclusively of Grasses and Sedges, forms with insignificant flowers destitute of coloured perianths and pollinated by wind.

Gramineæ.—Annual and perennial plants with upright, jointed haulms, and in the case of perennials, provided with creeping rhizomes. The leaves consist of an

undivided, linear, parallel-veined lamina (vol. i. fig. 150 [9]), and a sheathing basal portion. At the junction of blade and sheath is inserted a little scale—the ligule. Flowers hermaphrodite and unisexual, arranged in spikelets (*cf.* fig. 231, p. 139). Perianth absent, its place being taken in many cases by 2 tiny scales, the *lodicules*, sometimes regarded as reduced perianth-leaves. Each flower is inclosed in a sheathing scale known as a *palea*, whilst outside this and subtending the flower is a bract-like structure, the *flowering glume*; this is often awned. Every flower is thus inclosed in a palea and flowering glume, whilst the whole spikelet is inclosed in a little 2-leaved involucre consisting of 2 outer glumes. The ovary bears 2 feathery stigmas, and contains a single ovule. The stamens are generally 3 in number, though variations are met with. The pollen is dust-like. Pollination has been fully described on pp. 140–142. The fruit or grain is indehiscent, and is known as a *caryopsis*. The seed contains a floury endosperm, and an embryo placed at one side (*cf.* vol. i. figs. 141 [3, 4, 5], p. 599). The internodes of the haulm are in *Zea*, *Andropogon*, *Panicum*, &c., filled with pith; in the majority of Grasses they are hollowed. The Bamboos and numerous other tropical Grasses have upright perennial stems, and form an arborescent vegetation (*cf.* vol. i. p. 713). Bamboos attain a height of 25 metres and a diameter of nearly half a metre. But the majority of Grasses produce new haulms each year from their subterranean rhizomes, and these die down at the end of the season. The female flowers of the Maize (*Zea Mais*) are borne on thick spadices (cobs) inclosed in sheathing bracts. Grasses are widely distributed over the globe, the tropics being richer in species than the temperate regions, but poorer in individuals. Grasses are found extending into arctic and alpine regions to the extreme limits of phanerogamic vegetation; thus in the Alps *Poa laxa* has been found at an elevation of 3000 metres. The Bamboos are tropical and sub-tropical; in the Steppes certain Grasses are very predominant, *e.g.* the genera *Stipa* and *Festuca* (*cf.* Plate VI. vol. i. p. 616). In moist, temperate climates, Grasses form a continuous carpet, the basis of meadow land. In marshy places and by river banks reed-like Grasses occur in great quantities (e.g. *Phragmites communis*).

Gramineæ number about 3500 species.

Cyperaceæ.—Annual and perennial plants with upright, haulm-like stems, jointed below and with long upmost segment. The leaves much resemble those of Gramineæ, but the ligule is wanting. Flowers hermaphrodite and unisexual, aggregated into spikelets, inclosed in bract-like scales. Perianth absent, or represented by scales, bristles, or hairs. The ovary is 2- or 3-carpellary. Stamens in one or two whorls of 3 each; pollen dust-like, pollination by wind. The seed contains endosperm. In the Scirpeæ the leaf-blades are frequently obsolete, and assimilation is carried on by the stems. *Scirpus lacustris* reaches a height of 1, *Papyrus antiquorum* (or *Cyperus Papyrus*, fig. 424) of 3 metres and a diameter of 10 centimetres. The pith of the larger flowering stems of this plant cut into thin strips, united together by narrowly overlapping margins, and then crossed under pressure by a similar arrangement of strips at right angles, constituted the papyrus of

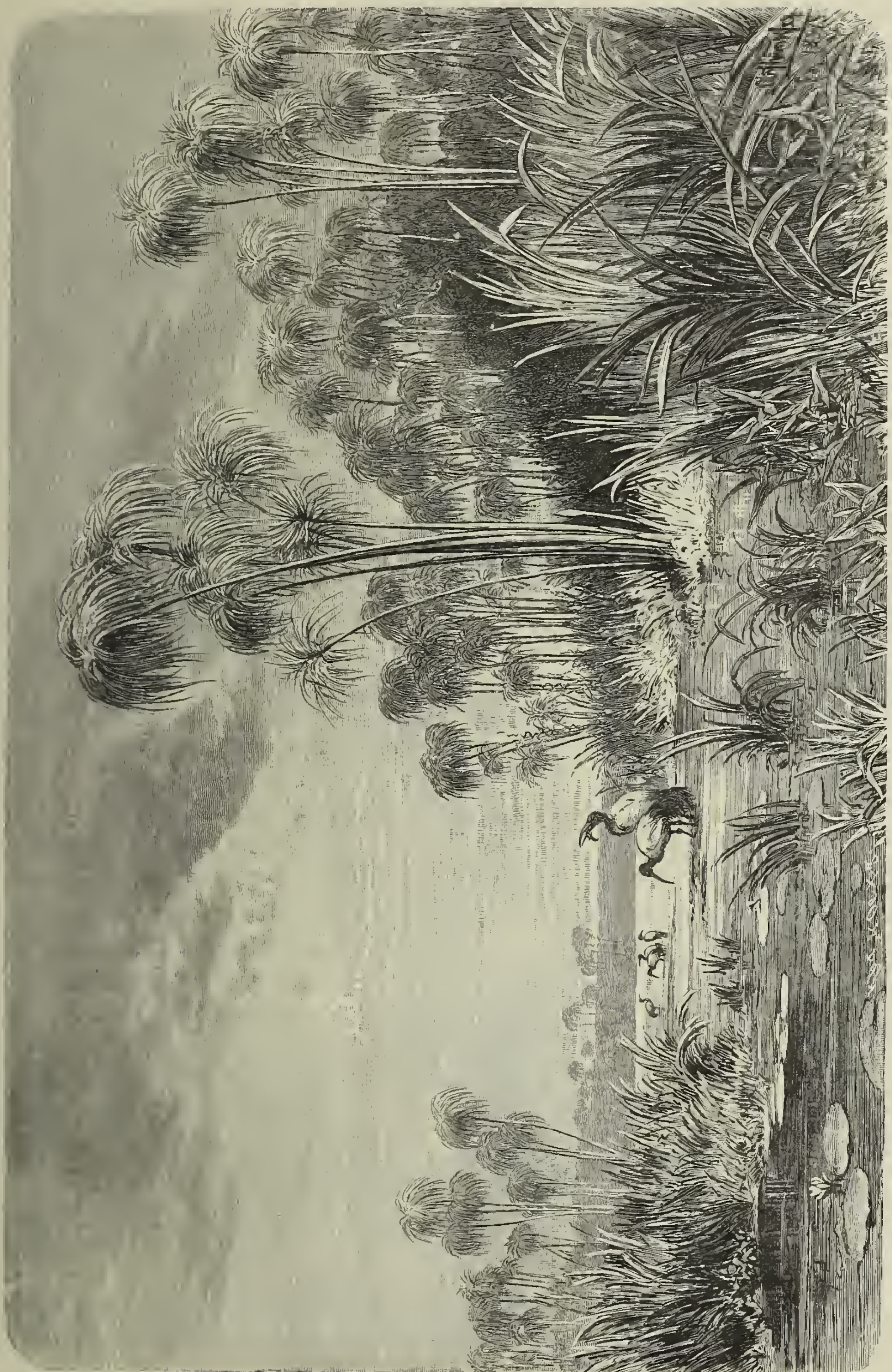


Fig. 424.—*Papyrus antiquorum* in the Upper Nile.

antiquity; it grows in the Upper Nile, Syria, Palestine, &c. The stem of Papyrus bears at the summit an umbel-like tuft of filamentous branches, upon which the inflorescences arise. Cyperaceæ grow for the most part on damp moors, and by the banks of streams and lakes, and in mountain regions. Many of them are social forms, noteworthy in this respect being *Carex stricta*, which forms hummocks in marshy places, standing up above the water, often thousands together. Several Sedges, e.g. *Carex sempervirens* and *C. firma*, contribute largely to the turfy carpet of alpine slopes (*cf.* Plate XII.).

The family is distributed over the whole world. *Carex*, *Eriophorum*, and *Scirpus* are found especially in cooler and northern zones; *Cyperus* and *Papyrus* in warmer regions. About 2500 species are known.

Class II.—DICOTYLEDONES.

Flowering Plants whose flowers typically have their parts arranged in whorls of four or five, embryos with two cotyledons, vascular bundles arranged in a ring and undergoing a secondary increase in thickness, leaves more complex than in Monocotyledones and usually reticulately veined.

The Dicotyledones may be divided into three Sub-classes: *Monochlamydeæ*, *Monopetalæ*, and *Polypetalæ*. The Monochlamydeæ have a simple perianth, or in some cases the perianth may be wanting. The Sub-class is an artificial one, as it includes forms whose ancestors probably possessed a double perianth and others which are primitively simple. The Monopetalæ and Polypetalæ possess both calyx and corolla; in the former the parts of the corolla are united together, in the latter free.

Sub-class I.—Monochlamydeæ.

Alliance XXXV.—**Centrospermæ.**

Families: *Piperaceæ, Polygonaceæ, Cynocrambaceæ, Urticaceæ, Chenopodiaceæ, Nyctaginaceæ, Amaranthaceæ, Paronychiaceæ, Caryophyllaceæ.*

Annual or perennial herbs, shrubs, and trees. Venation of the leaf-blades palmate or pinnate. Flowers solitary or in cymes; the cymes arranged in fascicles, glomerules, or spikes. Flowers actinomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves in one or two whorls; all sepaloid, all petaloid, or (in a few cases) the outer whorl sepaloid and the inner whorl petaloid. Where a corolla is developed the petals are free. In the case of diœcious flowers there is no difference between the male and the female flowers in respect of the development of floral-leaves. The ovary is superior; 1–5-carpellary, unilocular. The ovules are borne in the centre of the ovary on a stalk which rises from the bottom of the ovary, and is sometimes long, sometimes short. Stamens 1–30, arranged in one or two whorls, the outer ones inserted in front of the sepals or sepaloid perianth segments. Fruit an achene, capsule, or berry. The seed contains an abundant farinaceous or mucilaginous endosperm. Cotyledons not thickened.

The Centrospermæ are extremely rich in inorganic salts, and in the case of many of the species soda is extracted from the ash obtained by burning the plants. The Piperaceæ contain aromatic and pungent substances; the Urticaceæ secrete enzymes in their stinging-hairs (see vol. i. p. 441). The leaves are lobed in Urticaceæ and Chenopodiaceæ, in the rest they are undivided and have entire margins. In several Chenopodiaceæ the cauline leaves are squamiform, and assimilation is then effected by the green cortex of the branches, which are transformed into phylloclades. The Piperaceæ are distinguished by a peculiar distribution of the bundles in the foliage-leaves. The lateral strands do not branch off from the midrib in the usual way, but are appressed to it and can be traced to the base of the lamina. The Urticaceæ also, particularly the genus *Parietaria,* exhibit a peculiar disposition of the bundles (see vol. i. p. 629). The Chenopodiaceæ are destitute of stipules, the Paronychiaceæ have large membranous stipules which protect the foliage-leaves, the Polygonaceæ are distinguished by curious sheathing stipules. In the Caryophyllaceæ and some Paronychiaceæ the floral envelopes are differentiated into calyx and corolla; in Nyctaginaceæ, Amaranthaceæ, and most Polygonaceæ there is a petaloid perianth, whilst in Chenopodiaceæ and Urticaceæ there is a sepaloid perianth. The perianth in Nyctaginaceæ resembles a corolla most strongly when the bracts are connate and form a sepaloid envelope or involucre, as is the case, for instance, in the Marvel of Peru (*Mirabilis Jalapa,* see fig. 425). The lowest portion of the perianth in Nyctaginaceæ continues to grow after the flower has faded and forms a leathery or woody investment to the fruit (see fig. 425 [2]). In several Chenopodiaceæ and

Fig. 425.—Nyctaginaceæ, *Mirabilis Jalapa.*
1 Flowering branch. 2 Fruit inclosed in the persistent base of the perianth. 3 Longitudinal section through the same; the true fruit is seen within. (After Baillon.)

Urticaceæ also the perianth persists as a similar investment (e.g. *Morus*). In Amaranthaceæ the pedicels are furnished with bracts which resemble the perianth-segments and, like them, envelop the fruit. In those Centrospermæ which are destitute of floral-leaves (*achlamydeous*), *e.g.* the Piperaceæ, the floral envelopes are replaced by bracts. The Caryophyllaceæ have distinct calyx and corolla, and are often placed in the sub-class Polypetalæ; they have, however, decided affinities with the Centrospermæ. The andrœcium is composed of one whorl in Urticaceæ and Chenopodiaceæ, and of two whorls in most of the other families. The filaments are inflexed in the bud in Urticaceæ, but spring up when the perianth opens and so eject the pollen from the anthers (see p. 306). Most of the Centrospermæ have dust-like pollen, but in Caryophyllaceæ and Nyctaginaceæ the pollen is adhesive. In Urticaceæ and in some Caryophyllaceæ the embryo is erect, in the rest it is horse-shoe shaped or spirally curved (see fig. 425 [3]). The copious farinaceous endosperm of some Polygonaceæ and Chenopodiaceæ (*Polygonum Fagopyrum, P. Tataricum, Chenopodium Quinoa*) is used for flour. The Centrospermæ are distributed in every quarter of the globe. The Piperaceæ, Urticaceæ, Polygonaceæ, Amaranthaceæ, and Nyctaginaceæ are developed in the greatest variety in the tropics. Most Centrospermæ, however, are found in the temperate zones. The Mediterranean Flora is especially rich in Caryophyllaceæ, whilst Equatorial America abounds particularly in Amaranthaceæ and Nyctaginaceæ. The Polygonaceæ grow chiefly on the banks of streams; the Chenopodiaceæ are very prevalent by the sea-shore and on salt steppes, especially in Central Asia. Several Caryophyllaceæ flourish also on the confines of perpetual snow. *Silene acaulis* (see Plate XII.) is one of the most remote outposts of the Phanerogâmia and has been met with in Franz Joseph's Land at 81° north latitude, and in the Central Alps at a height of 3160 metres above the sea-level. Fossil remains of Urticaceæ and Piperaceæ have been recognized in the deposits of the Mesozoic and Tertiary periods. The number of species now living amounts to about 4200.

Alliance XXXVI.—Proteales.

Family: *Proteaceæ.*

Perennial herbs, with underground stems which project but little above the earth, or herbs and small trees with entire or variously lobed and incised stiff foliage-leaves without stipules. Flowers in capitula or spikes (see fig. 426 [1]); actinomorphic or zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious and diœcious. Perianth 4-partite, petaloid; the four segments are connate at the base, and, in the bud, have their free ends closed together like valves (see fig. 426 [2]). Ovary superior, free, unilocular. Number of ovules one to many. Placentation parietal. Each ovule has a double integument; the micropyle is directed towards the base of the ovary. The latter is surrounded by tissues which secrete honey. The number of stamens is equal to that of the perianth segments; the short filament is adnate to the perianth-segment behind it (see fig. 426 [3]). Fruit a drupe, a nut,

a capsule or a follicle (see figs. 426 [4] and 426 [5], and fig. 324, p. 429). The seed contains an embryo furnished with two large, thick, fleshy cotyledons, but no endosperm.

The Proteales are for the most part much-branched shrubs. The arboreal

Fig. 426.—Proteales.

[1] *Banksia ericifolia.* [2] Single flower of *Banksia littoralis* with the spoon-shaped perianth-segments still closed. [3] Longitudinal section through the same flower; the style is in the form of a barbed hook, and the stigma rests between the anthers; the filaments are adnate to the concave surfaces of the spoon-shaped perianth-segments. [4] Fruiting spike of *Banksia ericifolia.* [5] Fruit of *Xylomelum pyriforme.* [2] and [3] magnified; the rest nat. size. (After Baillon.)

species *Knightia excelsa,* a native of New Zealand, attains a height of 30 metres. The foliage-leaves are sometimes glabrous and sometimes clothed with scales, and they possess peculiar stomata (see vol. i. p. 296). The genus *Hakea* exhibits in

some of its species pinnate and bipinnate leaves, in others cylindrical and needle-shaped leaves. The flowers, which are crowded together, are sometimes surrounded by an involucre of many scales reminding one of the involucre of Compositæ. The ovary is often borne on a special stalk. The style and stigma are very various. In many species, as, for instance, in *Banksia ericoides* and *B. littoralis* (fig. 426 [3]), the style is hooked and breaks through the perianth-tube in consequence of the excessive longitudinal growth of its lower region, but the capitate extremity remains between the anthers, which are adherent to the spoon-shaped extremities of the perianth. Only when the perianth segments disunite and open back does the top of the style become free. The pollen is often deposited upon the end of the style without, however, immediately reaching the stigmatic surface, and in many species there are special hairs or brushes for collecting the pollen, whilst pockets and recesses for its temporary reception also occur. The Proteales flourish chiefly in regions where a short rainy season alternates a long rainless period. Australia and the south-west district of the Cape are richest in species; the alliance is represented by many fewer species in the tropical region of South America, in Chili, in New Caledonia, in New Zealand, in the tropical parts of Eastern Asia, in Madagascar, and in the mountains of tropical Africa. Fossil remains of Proteaceæ occur in strata of the Tertiary Period. The number of existing species is about 1000.

Alliance XXXVII.—Daphnales.

Families: *Elæagnaceæ, Thymelaceæ, Lauraceæ.*

Annual and perennial herbs, shrubs, and trees with green foliage, or leafless parasites. Stipules absent. Flowers in fascicles (see fig. 427 [1]); actinomorphic, hermaphrodite, pseudo-hermaphrodite, or diœcious. Perianth of one or two whorls of 2, 3 or 5 leaves each, sepaloid or petaloid. Gynæceum 1–3 carpellary. Ovary unilocular. Style single, free, at the bottom of a cup-shaped receptacle from the margin of which spring the perianth-leaves (see fig. 427 [2]). Ovule solitary. Andrœcium 1–4 whorls with 2–4 stamens in each inserted on the inner margin of the cup-shaped receptacle. Fruit a one-seeded berry, drupe, or nut. The seed contains no endosperm. The embryo is furnished with large, fleshy cotyledons.

The Cassythæ, belonging to the family Lauraceæ, are parasites poorly supplied with chlorophyll, with thin twining stems and squamiform leaves. Most of the Daphnales, however, develop woody stems with leafy branches. The leaves of Elæagnaceæ are clothed with scaly covering-hairs (see vol. i. p. 322, fig. 78 [5]). The foliage-leaves of most Lauraceæ exhibit a curious distribution of the strands in the laminæ (see vol. i. p. 631, fig. 149 [4], and accompanying fig. 427 [1]). The majority of Lauraceæ contain ethereal oils and aromatic substances. Especially to be mentioned in this connection are the Bay-Laurel (*Laurus nobilis*), the Cinnamon-tree (*Cinnamomum Zeylanicum*), and the Camphor-tree (*Camphora officinarum*). In the Sea Buckthorn (*Hippophae*, see p. 109, fig. 220), the perianth is 2- and the andrœcium 4-membered; in *Elæagnus* the perianth and andrœcium are each composed of two

2-membered whorls; in *Daphne* the perianths has two 2-membered whorls, and the andrœcium two 4-membered whorls (see fig. 427 [3]); in *Laurus* the perianth consists of two and the andrœcium of four 3-membered whorls; in the genus *Gnidium* there are two kinds of floral-leaves, the lower ones sepaloid the upper petaloid in colour, and these are spoken of as calyx and corolla. The same arrangement is found in several Lauraceæ. The anthers of Elæagnaceæ and Thymelaceæ dehisce by longitudinal slits, those of Lauraceæ by valves (see fig. 427 [2]). In the Elæagnaceæ the cup-shaped receptacle persists as an envelope around the fruit, and becoming succulent

Fig. 427.—Daphnales.

[1] *Camphora officinarum* (Family Lauraceæ), flowering branch. [2] Longitudinal section through the flower of *Cinnamomum Zeylanicum* (Family Lauraceæ). [3] Flower of *Daphne Mezereum* (Family Thymelaceæ) cut open and rolled back [1] reduced: [2] and [3] magnified. (Partly after Baillon.)

outside and strong within, the result is a false drupe. In some of the Lauraceæ also, as, for instance, in *Nectandra,* the receptacle continues to grow with the fruit, and forms a cup-shaped envelope resembling the so-called cupule in the fruit of the Oak. In Thymelaceæ and Lauraceæ the ovule is pendulous (see fig. 427 [2]), in Elæagnaceæ it is erect. The Daphnales are scattered over all parts of the earth. The Thymelaceæ are best represented in countries where the climate is temperate; the Cape and Australia are particularly rich in species of that family. *Daphne striata* attains its highest elevation in the Central Alps at 2500 metres. There is a striking concentration of several species of the genus *Daphne* on a strictly limited area in the mountainous parts of Southern Europe. One of these species is the plant known in Carniola under the name of the Königsblume (*Daphne Blagayana*).

This name of King's Flower was popularly accorded to the plant because, in 1838, King Augustus of Saxony travelled to Carniola on purpose to see this rare species flowering in its restricted habitat. The Lauraceæ are principally tropical and sub-tropical plants; Eastern Asia, the Sunda Islands, and Brazil are especially rich in species of this family. The Lauraceæ reach their northernmost boundary below 50° in Eastern Asia, below 46° in Europe, and below 45° in North America. In the Southern Hemisphere the Lauraceæ range as far as 43° S. lat. Fossil remains of the Daphnales, especially of Lauraceæ, are found in the strata of the Mesozoic and Tertiary Periods. The number of existing species hitherto discovered is about 1400.

Alliance XXXVIII.—Santalales.

Families: *Santalaceæ, Viscaceæ, Loranthaceæ, Olacaceæ, Grubbiaceæ.*

Herbs, shrubs, and trees, of which most are parasitic on the roots and stems of other green-leaved Phanerogams, although they are themselves capable of assimilation owing to the presence of chlorophyll in the foliage-leaves. The leaves have entire margins; there are no stipules. Flowers actinomorphic, solitary or in cymes, which are combined into spikes, racemes, umbels, and capitula; hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Perianth composed of 2- or 3-membered whorls; either sepaloid or petaloid. Gynæceum 2–3 carpellary; ovary sunk in the discoid or cup-shaped receptacle, inferior or semi-inferior, unilocular. Style single. Ovules 1–5, without integument. Stamens as many or double as many as the perianth-segments; in the former case they are inserted in front of those segments. Fruit usually a berry or drupe. Seed-coat either single or absent; the embryo either partially or entirely surrounded by fleshy endosperm.

For a description of the sinkers and haustoria of the parasitic Santalaceæ see vol i. p. 177 and pp. 205–213. Several of the Loranthaceæ have thin twining stems which put out roots, *i.e.* sinkers, from their nodes. Such of the Loranthaceæ as are destitute of green foliage-leaves have thickened and flat expanded branches. In certain Santalaceæ several bracts are united so as to form a cup-shaped involucre. In Grubbiaceæ and Olacaceæ the lower portion of the ovary is septate, at least in the first stage of development. In the Santalaceæ and some Olacaceæ 1–5 pendulous ovules are borne upon a cellular structure which is either adnate to the internal wall of the ovary or else rises freely in the cavity; in the Loranthaceæ they completely fill the ovary, and are united with the carpels into a solid mass. In Grubbiaceæ the stamens of the outer whorl alternate with the leaves of the perianth, and there are double as many stamens as perianth-segments. The stamens of the Mistletoe (*Viscum album*, see p. 87, fig. 214 [22]) are adnate to the perianth-leaves behind them, and their anthers have 6–20 loculi, each of which liberates pollen through a pore. The Santalales are widely distributed. The majority of the species are tropical and sub-tropical. The Olacaceæ only occur in the tropical parts of South America and Africa, and the Grubbiaceæ only at the Cape, whilst the Santalaceæ are chiefly natives of Africa and Australia. The

Mistletoe (*Viscum album*, found in Scandinavia as far north as 59° 30′) and several species of the genus *Thesium* reach furthest north. *Thesium alpinum* attains its highest limit in the Alps at 2400 metres. Fossil remains occur in the strata of the Tertiary Period. The number of existing species is about 750.

Alliance XXXIX.—Rafflesiales.

Families: *Rafflesiaceæ*, *Apodanthaceæ*, and *Cytinaceæ*.

Plants destitute of chlorophyll, parasitic on the roots of green-leaved woody plants. Flowering axis greatly thickened, fleshy. Flowers solitary or in racemes, hermaphrodite or pseudo-hermaphrodite. Perianth 4–6 partite. Ovary inferior. The cavity of the ovary is divided irregularly into chambers which are filled with strands and ridges bearing the ovules. Above the ovary rises a columnar style with a discoid thickening at the top, and upon the under margin of this disc the stigmatic tissue is situated. The stamens are inserted underneath the stigmatic tissue in a circle. The fruit is fleshy, baccate, and crowned by the persistent column. The seeds have hard coats. The embryo consists of few cells, has no cotyledons, and is surrounded by an oily endosperm. For a description of the suction-organs see vol. i. pp. 199–204, and for the size of the flowers see vol. ii. p. 185. The Rafflesiales live in the tropical and sub-tropical regions of both the Old and the New World; two species of the genus *Cytinus* (see vol. i. p. 201) belong to the Mediterranean flora. No fossil remains are known. The number of extant species hitherto identified is 29.

Alliance XL.—Asarales.

Families: *Aristolochiaceæ*, *Asaraceæ*.

Perennial plants, some with subterranean tuberous or creeping rhizomes, some with twining liane-like stems (see vol. i. fig. 95 [1], p. 364). Foliage-leaves broad, with entire margins, sometimes lobed. Venation apical (see vol. i. p. 633). Flowers hermaphrodite, solitary, or in cymose inflorescences, especially in axillary fascicles. Perianth of 3 petaloid leaves, united at the base. Gynæceum 4–6 carpellary; ovary inferior or semi-inferior. Styles united into a column bearing a radiating stigma. Andrœcium composed of 2–12 whorls of 3 stamens each. Ovules numerous in the loculi of the ovary. Fruit a capsule (see p. 431, fig. 325 [5]). The seed contains an abundant endosperm, and a very small embryo with two cotyledons.

The perianth in Asaraceæ is actinomorphic (see p. 279, fig. 279 [12, 13]), whilst in Aristolochiaceæ it is zygomorphic or else unsymmetrical, and the tube of the perianth is variously curved and inflated (see p. 166, fig. 242, and p. 226, fig. 257 [6, 7, 8, 9]). These flowers are very striking, on account not only of their form, but also of their dark-brown colour; moreover, in many cases they attain to an extraordinary size. Mention has already been made of *Aristolochia gigas* (see p. 185), and recently a Birthwort (*Aristolochia Goldeana*) has been found in West Africa which

has a perianth 66 cm. long and 28 cm. broad. In the Asaraceæ there are sometimes three small teeth alternating with the three perianth-segments, and these are looked upon as reduced inner perianth-segments. The stamens of Aristolochiaceæ are adnate to the stylar column (see p. 292, fig. 284 [12]). The Aristolochiaceæ are distributed in all parts of the world. The majority of the species are found in tropical and sub-tropical regions. The genus *Asarum* reaches furthest north. The northern limit of the Asarabacca (*Asarum Europæum*) and its highest elevation are the same as those of the Beech. Fossil remains are found in the strata of the Mesozoic and Tertiary Periods. The number of extant species hitherto identified is about 200.

Alliance XLI.—**Euphorbiales.**

Family: *Euphorbiaceæ.*

Annual and perennial herbs, shrubs, and trees. Flowers in racemose or umbellate cymes; actinomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves differentiated into calyx and corolla. Calyx and corolla 3–12-merous. The corolla is often suppressed, and sometimes the calyx also is wanting. In these cases the floral-leaves are replaced by bracts and involucral leaves. The gynæceum is superior, and is composed of 3–20 carpels, which are arranged in whorls round a central column. The carpels are joined together to form a multilocular pistil. In the inner angle of each loculus are 1–2 pendulous ovules. The stamens vary in number from 1 to over 100. At the base of the flower are some peculiar glands, which are looked upon as outgrowths of the receptacle. They are either in the form of separate cellular structures, arranged in a whorl, or else are coherent in the form of a cup. In the cases where these structures do not occur they are replaced by similar glands, which are seated upon the margin of the cup-shaped involucre. The fruit is a schizocarp or drupe; sometimes it is baccate. The embryo is imbedded in an abundant fleshy endosperm.

It is difficult to describe the Euphorbiales in few words on account of their extraordinary variety. Some of them contain watery juices; the majority are full of latex. Several of the laticiferous species are poisonous. Many have green foliage-leaves; whilst some are destitute of foliage-leaves, and assimilation is then effected by means of the green cortical tissue of switch-like or cactiform branches and phylloclades. In many genera, especially in *Euphorbia*, the inflorescences have the appearance of being single flowers. A large number of male flowers are assembled together within a cup-like involucre, the free edge of which is furnished with glands as though with petals. Each of these flowers consists, however, merely of a bract and a stamen, and in the midst of them is a female flower, borne at the end of a long stalk, and resembling a stalked ovary. In many species of the genera *Croton* and *Poinsettia* the inconspicuous flowers are surrounded by bright-coloured bracts and involucral leaves. In the majority of instances three carpels are developed, which are remarkable for their rotundity. They are laterally coherent, and usually separate when mature, and become detached from the central column. The

Euphorbiales are distributed in every quarter of the globe. The majority are found in the tropics, and several arboreal species form entire woods in those regions. Some grow in marshy lowlands, whilst others inhabit steppes and the rocky declivities of mountains. *Euphorbia capitulata* grows on the mountains of the Balkan Peninsula. *Euphorbia Austriaca* stretches as far as the alpine region of the Eastern Alps. *Mercurialis perennis* attains in the Alps an elevation corresponding to the upper limit of the Beech-forests. Several annual species of *Euphorbia* are encountered as weeds in cultivated ground, as far as the limits of the arctic region. Fossil remains have not been definitely ascertained to exist. The number of extant species hitherto identified is about 4000.

Alliance XLII.—**Podostemales.**

Family: *Podostemaceæ.*

Perennial herbs with creeping roots which are fastened to the substratum. The shoots spring laterally from these roots, and are clothed by small scales arranged in two or three rows; these leaves are either entire or pinnately lobed, and they are sheathed at the base. Not infrequently the shoots are transformed into phylloclades, and sometimes shoots and roots are fused together into a thalloid structure. In these cases the assimilation of carbon is effected by the phylloclades as well as by the green branches of the thalloid tissue clinging to the substratum. The branches in question are ribbon-shaped or filiform, and are submerged. The flowers occur singly at the ends of the shoots, or else are sunk in the margins of the phylloclades in rows, and together form a sort of flat club. They are actinomorphic and zygomorphic, hermaphrodite, monœcious, and diœcious. The floral-leaves are small, greenish, squamous, free, or connate, and are arranged in a 3–5-partite whorl. When the floral-leaves are suppressed, they are replaced by sheathing involucral leaves. The gynæceum is composed of 1–3 carpels; the ovary is superior, and either unilocular or else divided by delicate partition-walls into three chambers. The ovules spring from cushions of tissue which project from an axial column in the ovary. The number of stamens varies greatly, the flowers being either monandrous, diandrous, or polyandrous. In the last case the stamens are arranged in several whorls. The anthers dehisce longitudinally. The fruit is a capsule. The seeds are very small, and do not contain any endosperm. The embryo has two thick cotyledons.

The Podostemaceæ are found in running water, especially in waterfalls, clinging to rocks, loose stones, and stumps of trees which have been stripped of their bark. Almost all of them inhabit the tropics, the only exception being one species in South Africa and one in North America. No fossil remains have been found. The number of existing species hitherto described amounts to 175.

Alliance XLIII.—**Viridifloræ.**

Families: *Leitneriaceæ, Cannabinaceæ, Dorsteniaceæ, Artocarpaceæ, Ficaceæ, Conocephalaceæ, Moraceæ, Ulmaceæ*

Annual or perennial herbs, shrubs, and trees. The laminæ of the foliage-leaves veined with pinnate or radiating bundles. Flowers in glomerate, fasciculate, or spicate cymes; actinomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Perianth composed of 2–8 inconspicuous greenish segments. Gynæceum superior, 1–2 carpellary and unilocular. Ovule solitary, pendulous. Stamens as many or double as many as the perianth-segments; all or those of the outer whorl are

Fig. 428.—"Living bridge" formed of the aërial roots of the India-rubber and other kinds of Figs in Sikkim-Himalaya. (After Hooker.)

inserted opposite the segments of the perianth. The pollen in dusty. The fruit is a one-seeded achene or a drupe. The cotyledons of the embryo are not thickened.

The Ulmaceæ and Cannabinaceæ contain watery juices; the plants of the other families produce milky juice in greater or smaller quantity. The milky juice of the Indian *Ficus elastica* is used in the manufacture of caoutchouc, that of the South American Cow-tree (*Galactodendron utile*) as an article of diet. The milky juice of the Upas-tree (*Antiaris toxicaria*), native to Java, contains poisonous substances. In the Hop (*Humulus Lupulus*) and in the Hemp (*Cannabis sativa*) bitter and

Fig. 429.—Amentales.

[1] Birch (*Betula alba*) shoot with male and female catkins (the former at the apex). [2] Ripe female catkin of same. [3] Winged nut of same. [4] Subtending scale of fruit of same. [5] Shoot of Hornbeam (*Carpinus Betulus*) with male and female catkins (latter to right). [6] Scale of female catkin with flowers of same. [7] Scale from male catkin with stamens. [8] Scale of female catkin with ripe fruit. [3], [4], [6], [7] enlarged; the rest nat. size.

aromatic substances (lupulin and hashish) are produced in special cells and groups of cells. The curious tabular and columnar roots of the Ficaceæ have been described in detail and illustrated in vol. i. pp. 755–757. Here is represented a *Ficus* (fig. 428) with aërial roots, which Hooker saw used by the natives in the Himalaya as bridges. "The property of the fig-roots, which inosculate and form natural grafts, is taken advantage of in bridging streams, and in constructing what are called 'living bridges' of the most picturesque forms." The axis of the inflorescence is thickened in many cases, notably in the Dorsteniaceæ, Artocarpaceæ, Ficaceæ, Conocephalaceæ, and

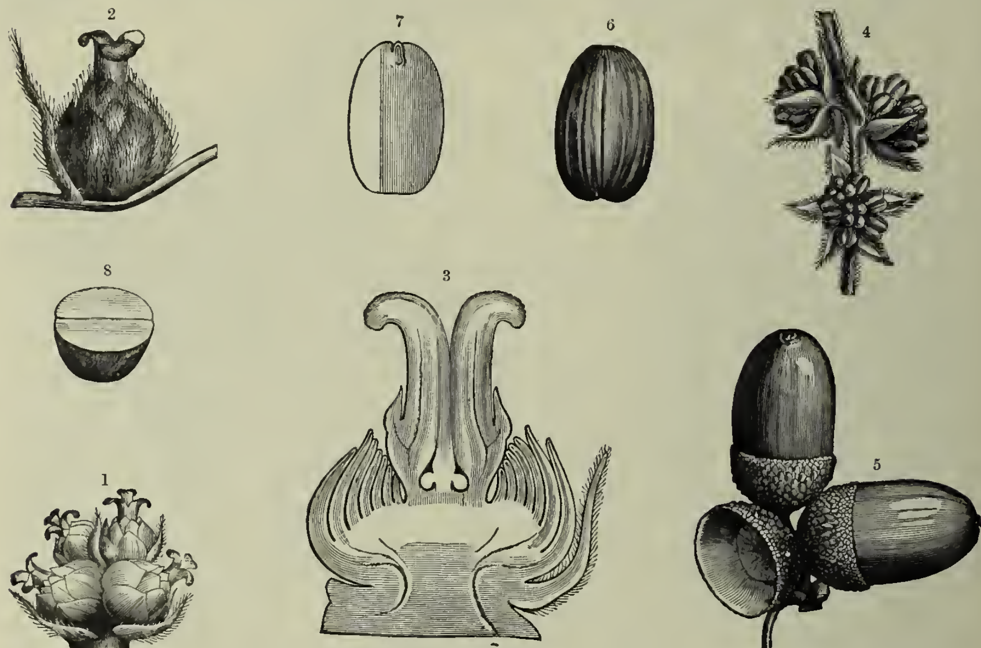


Fig. 430.—The Oak (*Quercus sessiliflora*).

1 Cluster of female flowers. 2 Single female flower. 3 Longitudinal section of a female flower showing the ovary with ovules, small perianth and the young cup or cupule. 4 Three male flowers. 5 Cluster of nuts (acorns) with their cupules. 6 The seed. 7 Longitudinal section of seed. 8 Transverse section of seed. 1, 2, 3, 4 enlarged; rest nat. size.

Moraceæ; sometimes it is discoid, and sometimes hollowed out into the shape of an urn (see p. 157). It also enters into the structure of certain fleshy succulent collective fruits, which afford such an important article of food in hot countries, viz. the figs of Ficus, and the Bread-fruit of *Artocarpus incisa.* Sometimes the perianth also takes part in the formation of the fruit, as, for instance, in the Mulberry (*Morus*), where it is converted into a fleshy envelope inclosing the fruit. On the other hand, in several other Viridifloræ the perianth is almost completely suppressed. In Dorsteniaceæ and Moraceæ the stamen-filaments are inflexed in the bud, and spring up after the perianth has opened, scattering the pollen-dust in the air (see fig. 229, p. 137). The filaments are straight in the flowers of the other families. The embryo is curved in most cases. There is either a very small quantity of endosperm or none at all. The Viridifloræ are found in all parts of the world. The Ulmaceæ extend

Fig. 431.—The Beech (*Fagus sylvatica*).

beyond 66° north latitude and 36° south latitude. Representatives of Viridifloræ are most abundant in the tropics. Fossil remains occur in the deposits of the Mesozoic and Tertiary Periods. The presence of leaves of a Bread-fruit tree (*Artocarpus Dicksoni*) in Greenland chalk, and of quantities of remains of Ulmaceæ (*Celtis, Zelkova, Ulmus*) in the Miocene strata, are points of special interest. The number of species ascertained to exist at the present day is about 1000.

Alliance XLIV.—Amentales.

Families: *Betulaceæ, Corylaceæ, Cupuliferæ, Juglandaceæ, Myricaceæ, Casuarineæ, Salicaceæ.*

Are all large shrubs and forest trees, forming a very conspicuous feature in the landscape in temperate climates. The flowers are unisexual and arranged in catkins or heads. Pollination is by wind, and, in the majority of cases, a perianth is wanting. In the Cupuliferæ, in which it is present, it is inconspicuous and consolidated with the ovary. The group is an exceedingly interesting one, owing to the recent discovery of several instances of chalazogamic fertilization within its limits; of this, full details were given at p. 413. In this alliance are included such familiar trees as the Birch (*Betula*, figs. 429 [1,2,3,4]), Alder (*Alnus*, p. 135), Hazel (*Corylus*, p. 147), Hornbeam (*Carpinus*, p. 433 and figs. 429 [5,6,7,8]), Oak (*Quercus*, p. 298 and fig. 430), Beech (*Fagus*, fig. 431), Chestnut (*Castanea*, p. 445), Walnut (*Juglans*), Sweet-gale (*Myrica*), *Casuarina*, and the Willow (*Salix*, pp. 299 and 424) and Poplar (*Populus*). Between 500 and 600 species have been distinguished. Members of this alliance date far back amongst the secondary rocks, and they are supposed by many to represent a primitive group of Angiosperms.

Alliance XLV.—Balanophorales.

Families: *Hydnoraceæ, Sarcophytaceæ, Cynomoriaceæ, Balanophoraceæ, Scybaliaceæ.*

Plants destitute of chlorophyll, parasitic on the roots of green-leaved woody plants, with tuberous, cylindrical, or angular stems with flowering lateral branches. The flowering axes are thickened and fleshy; the flowers hermaphrodite or pseudo-hermaphrodite, monœcious or diœcious. Perianth of 2–8 segments, sometimes transformed into a cup on the top of the ovary, or absent and replaced by scaly bracteoles and hairs. Gynæceum 1–3 carpellary; ovary inferior, unilocular, styles either absent or 1–2 in number, filiform, and terminating in small stigmas. Stamens 1–60 inserted below the limb of the perianth. Fruit a kind of berry, nut, or drupe. The embryo is very small, has no cotyledons, and is imbedded at the top of a fleshy, oily endosperm.

For a description of the suckers and scale-leaves, see vol. i. pp. 186–198. The flowers of Hydnoraceæ are solitary; those of Balanophoraceæ, Cynomoriaceæ, and Scybaliaceæ are crowded in large numbers on unbranched clavately-thickened axes,

and those of Sarcophytaceæ on branched clavate axes. In Hydnoraceæ the cavity of the ovary is occupied by numerous ridges which project from the walls and bear the ovules; in Sarcophytaceæ, Scybaliaceæ, Cynomoriaceæ, and Balanophoraceæ the placentation is parietal, and the number of the seeds is 3 in Sarcophytaceæ, 2 in Scybaliaceæ, 1–3 in Cynomoriaceæ, and 1 in Balanophoraceæ. In Hydnoraceæ and Sarcophytaceæ there is no style, and the free upper extremities of the masses of tissue which bear the ovules act as stigmas. The Cynomoriaceæ and Balanophoraceæ have one, and the Scybaliaceæ two, filiform styles with small papillose stigmas. In Hydnoraceæ the stamens are inserted between the lobes of the perianth, and form a fleshy ring; in the other families they stand in front of the segments of the perianth; in the Balanophoraceæ the filaments are connate. Most of the Balanophoraceæ live in the tropical parts of Asia and America; a few species inhabit South Africa and New Holland. *Cynomorium coccineum*, the only species of the Cynomoriaceæ, grows in the Mediterranean area and in Western Asia (see vol. i. p. 197, fig. 42). Fossil remains are not known. The number of extant species hitherto discovered is about 45.

Sub-Class II.—MONOPETALÆ.

Alliance XLVI.—**Caprifoliales.**

Families: *Rubiaceæ, Caprifoliaceæ*

Annual and perennial herbs, shrubs, and trees. The foliage-leaves are opposite, stipules are present at their bases (see fig. 432 [1]). The flowers are in cymes, actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. The floral-leaves are differentiated into calyx and corolla. The calyx is composed of one 2–6-sepalous whorl. The calyx-tube clothes the inferior ovary, whilst the limb consists of small green teeth. The corolla is a whorl of 3–6 connate petals (see fig. 432 [3]). The gynæceum is composed of 2–5 connate carpels; ovary inferior, 2–5 locular. The placentas are axile. The andrœcium is a whorl of 3–6 stamens, adnate to the corolla-tube. The pollen is either adhesive or powdery (see p. 265). The fruit is a berry, drupe, schizocarp, or capsule. The seed contains endosperm.

Most of the Rubiaceæ are herbaceous, whilst the species of the other families are mostly shrubby and arboreal plants. In the roots of several Rubiaceæ (e.g. *Rubia tinctorum* and *Galium boreale*) there is a red colouring matter (madder-red); the Coffeaceæ and Cinchonaceæ contain alkaloids (caffeine, quinine, &c.); the sweet-scented Woodruff (*Asperula odorata*), the herb used to make the German May-wine, is famous for the kumarin it contains. No laticiferous tubes or latex, however, are contained in the tissues of any species belonging to this alliance. The foliage-leaves are always opposite and in pairs, which are at right angles to one another; the venation of the laminæ is pinnate. In the Stellatæ section of Rubiaceæ the stipules are of the same size, colour, and form as the laminæ of the opposite leaves to which they belong, and are inserted between them. The consequence is that at each node there is a whorl of leaf-structures arranged in the form

of a star. In the Cinchonaceæ and Coffeaceæ, the stipules are squamiform, and sometimes lacerated (see fig. 432 [1]). In the Caprifoliaceæ they are either very small and in the form of stalked glands, or else they are adnate to the base of the petiole, and have the appearance of being narrow sessile segments of the leaf. The cymose inflorescences may be contracted into glomerules and fascicles, in which case each is surrounded by an envelope of bracts, as, for instance, in the Ipecacuanha plant (*Cephaëlis Ipecacuanha*; see fig. 432 [2]), or they may form pyramidal panicles, as in the *Cinchona*, or, lastly, they may be flat cymes, as in the Elders (*Sambucus nigra*

Fig. 432.—Caprifoliales: *Cephaëlis Ipecacuanha* (Family Rubiaceæ).
[1] Entire Plant. [2] Inflorescence. [3] Single flower. [1] reduced; [2] and [3] magnified. (After Baillon.)

and *S. Ebulus*). In the Caprifoliaceæ, especially in the genera *Linnæa* and *Lonicera*, two-flowered cymes also occur, and in several species of the genus *Lonicera*, the ovaries of the two flowers in each cyme are connate. The flowers of several Caprifoliaceæ (*Linnæa*, *Lonicera*, &c.) are zygomorphic, whereas the other members have actinomorphic flowers. In the Stellatæ the fruit is a schizocarp which breaks up into two mericarps; in Cinchonaceæ, it is a capsule which dehisces from the base upwards (see p. 431, fig. 325 [10]). In Coffeaceæ, Sambucaceæ, and the genus *Linnæa*, the fruit is a drupe, and in Gardenieæ and some of the Caprifoliaceæ, a berry. The baccate fruits of several species of the genus *Lonicera* (*L. alpigena* *L. cœrulea*, &c.), coalesce to form a collective fruit. Each chamber in the fruit of

Rubiaceæ, Coffeaceæ, Sambucaceæ, and of the genus *Linnœa*, contains one seed, in most Caprifoliaceæ, as in the genus *Lonicera*, several, and in the Cinchonaceæ, many seeds. The seeds of Cinchonaceæ are winged (see p. 423, fig. 318 [7]).

The Caprifoliales are distributed over all parts of the earth. The Coffeaceæ and Cinchonaceæ are chiefly tropical plants, whilst the Rubiaceæ, Sambucaceæ, and Caprifoliaceæ belong principally to the North Temperate Zone. The Cinchona is found wild only in the Cordilleras in South America (from 10° north lat. to 22° south lat.). Tropical Africa is supposed to be the original home of the Coffee-tree (*Coffea Arabica*). *Linnœa borealis*, a plant named after the Swedish botanist, Linnæus, is scattered over the Alps, in the low-lying part of Germany adjoining the Baltic, and in Scandinavia. Several species of the genus *Galium*, of the family Rubiaceæ, belong to the flora of the extreme North and of high mountains. Fossil remains have been preserved in the deposits of the Mesozoic and Tertiary Periods. The number of extant species discovered up to the present time is about 4800.

Alliance XLVII.—Asterales.

Families: *Valerianaceœ, Dipsaceœ, Calyceraceœ, Brunoniaceœ, Compositœ.*

Annual and perennial herbs, shrubs, and trees. Foliage-leaves extremely various in form but always destitute of stipules. Inflorescence a cyme or a capitulum. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves differentiated into calyx and corolla. Calyx of 2–5 sepals; the limb, which crowns the inferior ovary, is in the form of a pappus, bristles, scales, teeth, callosities, or membranous borders, and is destitute of chlorophyll. The corolla is composed of 4–5 connate petals. The gynæceum consists of 2–3 connate carpels. The ovary is inferior and contains only one developed loculus with a single ovule in it (see p. 73, fig. 207 [5]). The andrœcium consists of 1–5 stamens. The filiform filaments are adnate at the base to the corolla-tube. The fruit is a unilocular, one-seeded achene.

The plants belonging to this alliance exhibit for the most part herbaceous growth, but some Compositæ are shrubby (e.g. *Baccharis*), and some arboreal (e.g. *Vanillosmopsis, Lychnophora*). Several Valerianaceæ and Compositæ, *e.g.* the Dahlia and Jerusalem Artichoke (*Dahlia variabilis* and *Helianthus tuberosus*), are distinguished by underground tuberous structures. The inflorescence in Valerianaceæ is a much-branched cyme (see p. 305, fig. 289 [1]). In Dipsaceæ also the arrangement of the flowers is cymose, but the cymes are usually grouped together in capitula (see p. 121, fig. 225 [5]). In some genera, such as *Morina*, they are arranged in opposite fascicles in the same manner as in Labiatæ. The flowers of Compositæ are situated at the extremity of a thickened axis which is conical, hemispherical, or flat, and compressed, as the case may be; they are spirally arranged and are grouped together in capitula (see p. 242). In many cases they spring from the axils of scales ("paleæ"), or else their place of origin is surrounded by bristles. Not infrequently they spring from little depressions, and then the axis is seen to be pitted when the

flowers have fallen off. The number of flowers in a capitulum varies greatly. In many species several hundreds of flowers (florets) are crowded together, in *Adenostyles* and *Eupatorium* (see p. 320, fig. 294 [1]) there are only a few flowers in each capitulum, and in *Echinops* it is limited to a single one. The capitulum is surrounded by an involucre of bracts crowded together. The form of these involucral leaves exhibits extreme variety. In Thistles their apices are transformed into prickles, in the species of the genus *Xeranthemum, Helichrysum,* &c., they are like paper or parchment, dry, and distinguished by white, yellow, violet, and red colours. They preserve these characteristics unchanged even when dried, and can therefore be made up into bouquets and wreaths which do not fade. These composite flowers, which are known as "immortelles", are everywhere used as symbols of immortality and as memorial tokens. The Cape is exceptionally rich in Everlasting Flowers; among the species found there is *Helichrysum eximium*. The Edelweiss (*Gnaphalium Leontopodium*, see vol. i. p. 315, fig. 76) may also be looked upon as an immortelle, although here the bracts are not themselves dry and membranous, but are only covered with a dry, white felt of hairs. In many species the capitula are themselves grouped in capitula or glomerules. One of the most striking instances of this is afforded by the species of the genus *Haastia,* which are shown on p. 188. In the genus *Echinops* a large number of one-flowered capitula are grouped together in spherical heads, usually of a steel-blue colour. The capitula often look like single flowers, and in former times they were looked upon by botanists as compound flowers (*flores compositæ*), whence the name of Compositæ. In many species, *e.g.* the Sun-flower (*Helianthus annuus*), the capitula attain to a diameter of 40 centimetres. In the actinomorphic corollas a tube and a bell-shaped 5-partite limb may be distinguished (see p. 360, figs. 302 [1, 2, 3]). The zygomorphic flowers are either two-lipped, the upper lip being composed of one or two petals, and the under lip of four or three petals, or else ligulate, in which case the tube is greatly abbreviated and the free end of the ligule usually exhibits five segments or teeth (see p. 121, fig. 222 [4], and p. 236, fig. 261 [3]). In Valerianaceæ the corolla is usually produced on one side into a kind of sac, which in the genus *Valeriana* is short and blunt (see p. 289, fig. 283 [3]), and in the genus *Centranthus* is in the form of a long, slender, pointed spur (see p. 240, fig. 263 [2], and p. 305, figs. 289 [2, 3]). In the capitula of Compositæ the flowers with tubular, ligulate, and bilabiate corollas respectively are grouped together in a great variety of ways. It is not common for all the flowers of a capitulum to have tubular flowers, but that is sometimes the case (e.g. *Eupatorium*, p. 320, fig. 294 [1]); much more frequently all the flowers in a capitulum have ligulate corollas (e.g. *Hieracium*, p. 112, fig. 222 [5]), and in the majority of instances the flowers in the middle of the capitulum are furnished with tubular corollas, and those near the periphery with ligulate or bilabiate corollas (see p. 360, fig. 302 [1]). The distribution of the sexes has been dealt with on pp. 295–297, and pp. 318–321. In the Compositæ the anthers of the five stamens are united into a tube. The anthers are not connate in the other families. In Dipsaceæ the andrœcium consists usually of four stamens, and in Valerianaceæ usually of three stamens (see p. 289,

fig. 283 [3]); the genera *Morina* and *Fedia* have two stamens in each flower, whilst the genus *Centranthus* (Red Valerian) has only one (see p. 240, fig. 263 [2]). For a description of the pollen of Compositæ see p. 99. The gynæceum in Valerianaceæ is composed of three carpels, and the ovary is originally 3-locular, but two of the carpels are abortive, and only the third loculus is completely developed. In the other families the ovary is unilocular from the first. The ovule and the seed resulting from its development is pendulous (see p. 178, fig. 249, and p. 240, fig. 263 [2]) in Dipsaceæ and Valerianaceæ, basal (see p. 73, fig. 207 [5]) in Compositæ. In most cases the calyx remains adnate to the mature fruit and assumes the form of a crown of hairs or bristles, which is termed a "pappus" (see p. 432), or else constitutes a membranous limb. In a later chapter we shall deal with the significance of these structures. In the Dipsaceæ the fruit is surrounded by a saccate involucre called an involucel. The alliance is distributed over all parts of the earth; its members flourish both in the tropics and in the arctic regions, and are met with on the sea-shore and by the side of glaciers, in bogs and on arid ground, in shady woods and on sandy steppes. The greatest number are natives of the North Temperate Zone. In the Himalayas several Composites occur at an elevation of 4500 metres. Fossil remains have been found in small quantities in the deposits of the Mesozoic and Tertiary Periods. The number of extant species identified up to the present time is about 10,700.

Alliance XLVIII.—Campanales.

Families: *Campanulaceæ, Lobeliaceæ, Stylidiaceæ, Goodeniaceæ.*

Annual and perennial herbs with entire exstipulate foliage-leaves arranged spirally. Flowers in capitula or racemes, or else solitary; actinomorphic or zygomorphic, hermaphrodite or pseudo-hermaphrodite. Floral-leaves differentiated into calyx and corolla. Calyx of one whorl of 3–8 sepals, corolla of one whorl of 3–8 petals. The calyx-tube clothes the inferior ovary, and the calyx-limb is in the form of 3–8 comparatively large, green segments which crown the top of the ovary. The petals are joined. The gynæceum is composed of 2–5 connate carpels; the ovary is inferior and 2–5 locular. The ovules are numerous, and are borne on axile placentas. The andrœcium consists of one whorl of 3–8 stamens, which are attached to the bases of the petals. The filaments are free; in the young flower the anthers are in close contact, forming a tube surrounding the style (see p. 360, figs. 302 [10, 11]). Sometimes they are connate, and in that case the tube persists even when the flower begins to fade. The pollen is adhesive. The fruit is a capsule (see fig. 340 [1], p. 448).

All the Campanales have laticiferous tubes running through them, and in several species the leaves and stems are copiously supplied with latex. The flowers are actinomorphic in Campanulaceæ, zygomorphic in the other families. In the Stylidiaceæ, only two of the stamens develop pollen capable of effecting fertilization, whilst three stamens are abortive; in the other families all the stamens produce

pollen, which ripens effectually. The Campanales are distributed over all quarters of the globe. The Campanulaceæ are mostly natives of the North Temperate Zone, the Lobeliaceæ of the South Temperate Zone and the Tropics. Some Campanulaceæ are also found amongst the flora of the Arctic regions, and of high mountains. The Stylidiaceæ and Goodeniaceæ are confined to Australia. No fossil remains have been discovered. The number of identified species now living is about 1300.

Alliance XLIX.—Ericales.

Families: *Diapensiaceæ, Pyrolaceæ, Monotropaceæ, Lennoaceæ, Arbutaceæ, Rhodoraceæ, Ericaceæ, Epacridaceæ, Empetraceæ, Ebenaceæ, Sapotaceæ.*

Perennial herbs, shrubs, and trees. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. The floral-leaves arranged in two 3–5 partite whorls. The lower whorl constitutes a calyx, the upper a corolla. The petals are free in Pyrolaceæ and Monotropaceæ; in the other families they are coherent, at any rate at the base. The gynæceum is composed of 3–10 carpels; the ovary is superior, and 3–10 celled. The ovules arise from an axile placenta. The andrœcium is composed of one or more whorls of 4–5 stamens each. In many cases some of the stamens are metamorphosed into gland-like structures. The fruit is a capsule, berry or drupe. The embryo is erect, and imbedded in the fleshy endosperm.

The Diapensiaceæ and Pyrolaceæ (see figs. 277 [7, 8], p. 273), are perennial herbaceous, or suffruticose plants, which grow in black humus, and have stiff, evergreen foliage-leaves; the Monotropaceæ and Lennoaceæ are parasites or saprophytes (see vol. i. p. 252), and are destitute of chlorophyll. The Arbutaceæ, Rhodoraceæ, Ericaceæ, Epacridaceæ, and Empetraceæ are, for the most part, dwarf shrubs; only a few are trees. *Erica arborea*, one of the Mediterranean Flora, when able to grow without hindrance, attains the height of 8 metres. The branches of Ericaceæ, Epacridaceæ, Empetraceæ, and of *Loiseleuria* or *Azalea procumbens*, one of the Rhodoraceæ, are thickly covered with stiff, rolled leaves (see vol. i. p. 303 [2]). The species of the genus *Rhododendron* have flat foliage-leaves (see Plate X.), as have also the Arbutaceæ (see fig. 433[1]). The leaves of *Arctostaphylos alpina, Azalea Pontica,* and *A. mollis* are green in the summer only, whilst most of the Arbutaceæ and Rhodoraceæ have flat, evergreen foliage. The Ebenaceæ and Sapotaceæ exhibit, in a large proportion of their species, arboreal growth and leathery foliage-leaves. All the Ericales are distinguished for their solid timber. Some of the Rhodoraceæ have zygomorphic flowers; the rest of the Ericales have actinomorphic flowers. In *Loiseleuria*, and in the Empetraceæ and Epacridaceæ, the androecium is composed of one whorl; in the others it consists of two or more whorls. The anthers of Arbutaceæ and of many Ericaceæ possess two peculiar horn-like appendages (see figs. 433 [3] and 433 [4], and figs. 216 [9, 10, 11], p. 91). In Epacridaceæ the anthers are unilocular, and dehisce longitudinally; in Ericaceæ, Arbutaceæ, Rhodoraceæ, and Pyrolaceæ they usually open by terminal chinks or pores (see p. 91, figs. 216 [8, 9, 10, 11, 12]).

The pollen is dusty in Ericaceæ, but adhesive in most other cases. The pollen-cells are united in fours in Ericaceæ, Rhodoraceæ, and Pyrolaceæ, and in the Rhodoraceæ these groups are connected by tough threads (see figs. 219 [2, 3, 4], p. 101). The fruit is capsular in Diapensiaceæ, Pyrolaceæ, Monotropaceæ, Rhodoraceæ, Ericaceæ, and Epacridaceæ, and baccate in Arbutaceæ, Empetraceæ, Sapotaceæ, and Ebenaceæ. In the Lennoaceæ the fruit resolves itself into 10–28 one-seeded portions. The Ericales are distributed over the whole world; the Ebenaceæ and Sapotaceæ live chiefly in the tropics; the Lennoaceæ are confined to the southern half of North America, and the Epacridaceæ to Australia. The species of Ericaceæ are most abundant at the Cape. Most of the species of the genus *Rhododendron* inhabit

Fig. 433.—Ericales: *Arbutus Unedo* of the family Arbutaceæ.

1 Flowering branch. 2 Three flowers magnified. 3 Longitudinal section through a flower. 4 Flower from which the corolla has been removed. 5 Papillose berry. 2, 3 and 4 magnified. (After Baillon.)

the mountains of Central Asia, *e.g.* the Himalayas. The genus *Kalmia* belongs to the mountains of North America. The Diapensiaceæ live in the arctic regions, as also do several Ericaceæ. *Loiseleuria* or *Azalea procumbens* is widely distributed in the arctic regions, and also occurs in exactly the same form on the mountains of Central and Southern Europe; in the Central Alps it attains its maximum elevation of 2700 metres above the sea-level. Most of the Ericales grow sociably on rocky declivities in mountainous districts, and on sandy soil in plains. Many only flourish on moorland, or when rooted in a deep layer of humus, and these play an important part in the formation of peat. Fossil remains are found in the deposits of the Mesozoic, Tertiary, and Diluvial periods. The number of extant species known is about 2300.

Alliance L.—**Vacciniales.**

Families: *Vacciniaceæ, Oxycoccaceæ.*

Woody plants, presenting all gradations in form, from that of delicate dwarf shrubs lying upon the ground to that of stately trees. The foliage-leaves arranged spirally, exstipulate. Flowers in racemes and fascicles, or solitary; actinomorphic, hermaphrodite. Floral-leaves differentiated into calyx and corolla. The calyx is composed of a whorl of 4–6 sepals. The calyx-tube clothes the inferior ovary; the calyx-limb is in the form of short, green teeth, crowning the top of the ovary. The corolla consists of a whorl of 4–6 petals; the petals are united or free. The gynæceum is composed of 4–6 connate carpels. The ovary is inferior and 4–6-locular. The placentas are axile. A honey-secreting tissue is situated on the top of the ovary. The andrœcium consists of two whorls with 4–6 stamens in each. The stamens surround the nectary, and are free from one another and from the corolla. The members of the outer whorl are opposite the petals. The fruit is a berry or a drupe. The seed contains a fleshy endosperm.

The Vacciniales have no laticiferous tubes or latex. In Vacciniaceæ the petals are united, and the anthers are furnished with horn-shaped appendages, in Oxycoccaceæ the petals are free, and the anthers have no horns. The Vacciniales are distributed in all quarters of the globe, and in all latitudes. The species which belong to the Temperate Zones grow in peat-bogs and in the humus of woods and heaths, the species native to the mountains of tropical regions are, in some cases, epiphytic on the bark of old trees. Many are of social habit, and cover extensive tracts of ground. This is the case, for instance, with the various species of the genus *Vaccinium*: the Cow-berry (*Vaccinium Vitis-Idæa*), the Bilberry (*Vaccinium Myrtillus*), and *Vaccinium uliginosum*. These species are also found within the area of the Arctic Flora. *Vaccinium uliginosum* ranges furthest to the North, and in Greenland forms with the dwarf Birch (*Betula nana*) and dwarf Willows, a low undergrowth which reaches to 73° N. Lat. They clothe the mountain sides in the Central Alps as far as 2400 metres above the sea-level. Fossil remains have been found in the deposits of the Mesozoic, Tertiary, and Diluvial Periods. The number of extant species hitherto recognized amounts to about 350.

Alliance LI.—**Primulales.**

Families: *Primulaceæ, Plumbaginaceæ, Myrsinaceæ.*

Annual and perennial herbs, shrubs, and small trees with alternate, opposite, and verticillate foliage-leaves. Fowers solitary, or in spikes and racemes; actinomorphic, hermaphrodite or pseudo-hermaphrodite. The floral-leaves are arranged in two whorls of 4–8 segments each. The lower whorl constitutes a calyx, the upper a corolla. The petals are coherent. The pistil is superior, 5-carpellary, unilocular. The ovules are supported in the middle of the ovary on a column of varying length

rising from the bottom of the ovary. The stamens, five in number, are inserted in front of the petals, and are adnate to them (*epipetalous*). The fruit is a unilocular capsule or drupe. The seeds contain an endosperm, in which the embryo is embedded.

The ovary is surmounted by a single style in Primulaceæ and Myrsinaceæ, by five styles in Plumbaginaceæ. The capsules of Primulaceæ are many-seeded, those of Plumbaginaceæ are one-seeded. In the genus *Glaux* only one floral envelope is developed. It has the appearance of a perianth, and resembles that of Polygonaceæ. It is interpreted as being a petaloid calyx. The fact that in *Glaux* the stamens occupy the same position in relation to the sepals as the petals do in other cases warrants our supposing that what is usually designated as the corolla in Primulaceæ is only a whorl of stamens with connate petaloid filaments. The Primulaceæ are distributed mainly in the temperate zone of the Northern Hemisphere. Most of the species of the genera *Primula, Soldanella,* and *Androsace* are alpine plants. The Alps and the Himalayas are particularly rich in these species. *Androsace glacialis* (see fig. 221 [6]) occurs in the Alps in the neighbourhood of glaciers at a height of 3160 metres above the sea-level. *Primula pubescens,* a plant obtained by Clusius in 1582 from the Gschnitzthal in Tyrol, was the original species from which Auriculas were derived during the fashion for their cultivation which prevailed in the seventeenth century. The Plumbaginaceæ are represented by large numbers of species on the shores of the Mediterranean and in the saline steppes of the East. The Myrsinaceæ grow exclusively in the tropics. Fossil remains of Myrsinaceæ are known amongst the deposits of the Tertiary period. The number of species now existing is about 1100.

Alliance LII.—**Tubifloræ.**

Families: *Gentianaceœ, Asclepiadaceœ, Apocynaceœ, Loganiaceœ, Convolvulaceœ, Polemoniaceœ, Hydrophyllaceœ, Boraginaceœ, Nolanaceœ, Solanaceœ, Scrophulariaceœ, Lentibulariaceœ, Bignoniaceœ, Acanthaceœ, Gesneraceœ, Orobanchaceœ, Globulariaceœ, Plantaginaceœ, Myoporaceœ, Verbenaceœ, Labiatœ, Oleaceœ, Jasminaceœ.*

Annual or perennial herbs, shrubs, and trees. Flowers actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. Floral-leaves in two 4–5-partite whorls; the lower whorl in the form of a calyx, the upper in the form of a corolla. Petals united. Gynæceum 2- or more celled, ovary superior. The ovules are developed either on the turned-in margins of the carpels or on an axile placenta. The andrœcium is composed of a whorl of 2–5 stamens. The fruit is either a succulent berry, a capsule with various modes of dehiscence, or a drupe.

The Solanaceæ, Scrophulariaceæ, Loganiaceæ, and Asclepiadaceæ contain poisonous alkaloids, the Gentianaceæ contain bitter substances, and the Labiatæ contain etherial oils and aromatic substances. The majority of Tubifloræ possess green foliage-leaves. Some Scrophulariaceæ, *e.g.* the species of the genus *Rehmannia,* are

in the form of switch-shrubs, and several Asclepiadaceæ, *e.g.* the species of the genus *Stapelia,* have cactiform stems. In these the assimilation of carbon is effected by the green cortical tissue. The Orobanchaceæ are parasites destitute of chlorophyll (see vol. i. p. 183). Amongst Convolvulaceæ, and more especially amongst Scrophulariaceæ, there are many species which live as parasites and saprophytes, and are partially deficient in chlorophyll (see vol. i. pp. 171–183). An account has already

Fig. 434.—Acanthaceæ.

Acanthus mollis on the coast of Dalmatia.

been given of the way in which the Lentibulariaceæ, *e.g.* the species belonging to the genera *Utricularia* and *Pinguicula,* derive a portion of their food from the bodies of insects which are caught by them (see vol. i. pp. 120, 140). In Gentianaceæ, Oleaceæ, Apocynaceæ, Asclepiadaceæ, Convolvulaceæ, and many Boraginaceæ and Solanaceæ the corolla is actinomorphic. The Labiatæ, Scrophulariaceæ, Verbenaceæ, Acanthaceæ, Lentibulariaceæ, and some genera of Boraginaceæ and Solanaceæ bear distinctly zygomorphic flowers. In the Ash genus (*Fraxinus*), which belongs to the family of Oleaceæ, the corolla is often entirely suppressed. Most Labiatæ have four

didynamous stamens, but some of them, *e.g.* those of the genus *Salvia* (see fig. 271, p. 262), have two stamens, as have also the species of the genus *Veronica* (see fig. 257, p. 226) of the family Scrophulariaceæ, and the majority of the Jasminaceæ and Oleaceæ (see fig. 283 [2]). Most of the Tubifloræ possess five stamens. The curious modification of the andrœcium of Asclepiadaceæ has been fully described on p. 257,

Fig. 435.—Ranunculaceæ.

[1] *Helleborus niger* (reduced ½). [2] *Myosurus minimus*, complete plant with flowers and flower-buds (nat. size). [3] A single flower of *Myosurus* (magnified).

et seq. In the Apocynaceæ the two opposite carpels are separate at the base and connate at the upper end only. The fruit of Labiatæ and Boraginaceæ resolves itself when it is ripe into four one-seeded nutlets. The seeds of Apocynaceæ and Asclepiadaceæ are furnished with a plume of hairs. In most of the Tubifloræ the base of the pistil is partially or completely surrounded by swollen tissue which

secretes honey. The Tubifloræ are distributed in every quarter of the globe. Several families, such as the Loganiaceæ and Bignoniaceæ, are confined to tropical and subtropical regions. The Acanthaceæ also chiefly inhabit the warmer parts of the earth. The genus *Acanthus* grows particularly in the region of the Mediterranean Flora. The leaves of several species of *Acanthus*, e.g. *Acanthus spinosissimus* (see vol. i. fig. 116, p. 437) and *Acanthus mollis* (see fig. 434), frequently served the Greek and Roman sculptors as patterns for their ornaments. The genus *Stapelia*, of the family Asclepiadaceæ, is confined to the Cape; the Labiatæ are most abundantly represented in the Mediterranean Flora; the Gentianaceæ and Scrophulariaceæ inhabit mountainous regions of the Old and the New World in large numbers of different forms, and several species of the genera *Gentiana*, *Veronica*, *Euphrasia*, and *Pedicularis* thrive best in proximity to glaciers both in mountain districts and in the arctic regions. Fossil remains occur in the strata of the Tertiary period. The number of species now living which have been identified up to the present time is about 16,500.

Class III.—POLYPETALÆ.

Alliance LIII.—**Ranales.**

Families: *Ranunculaceæ, Dilleniaceæ, Calycanthaceæ, Magnoliaceæ, Anonaceæ, Menispermaceæ, Berberidaceæ, Lardizabalaceæ, Nymphæaceæ.*

Stamens rarely definite. Carpels, free or immersed in the receptacle, very rarely connate. Embryo minute, embedded in a fleshy endosperm. In the Ranunculaceæ the petals are not infrequently modified into honey-glands, and the sepals petalline. The carpels are free from one another, and sometimes indefinite and spirally arranged, sometimes definite and whorled. In *Calycanthus*, the parts of the flowers are inserted in a continuous spiral upon a hollow receptacle, and pass gradually the one into the other. In Berberidaceæ, the anthers open by means of valves. The Nymphæaceæ include marsh and water plants (e.g. *Nymphæa, Nuphar, Nelumbium*, *cf.* fig. 436, *Victoria Regia*, Plate XI.). In several of these the carpels are united together into a large ovary with shield-like stigmatic disc. In *Nelumbium* (*cf.* fig. 334, p. 440), the carpels are borne in distinct sockets. The fruit in the alliance is very varied, and includes achenes, follicles, berries. Fossil remains occur in the Tertiary Strata. Total number of living species about 3000

Alliance LIV.—**Parietales.**

Families: *Sarraceniaceæ, Papaveraceæ, Fumariaceæ, Cruciferæ, Capparidaceæ, Moringaceæ, Resedaceæ, Cistineæ, Violaceæ, Bixaceæ.*

Annual and perennial herbs, shrubs, and trees. Flowers solitary or in spikes, umbels, racemes, and racemose cymes; actinomorphic and zygomorphic, hermaphrodite and pseudo-hermaphrodite. Floral-leaves differentiated into calyx and corolla; the calyx composed of a 2–5-partite whorl, the corolla of two 2-partite

whorls or one 5-partite whorl. Petals free. Gynæceum composed of 2, 3, or several carpels joined together to form a unilocular (or spuriously bilocular), free, superior ovary. Ovules attached to the interior walls of the carpels on ridges, or springing directly from the walls of the ovary (see fig. 437 [1]). The andrœcium is composed of either one whorl or many whorls of 2–5 stamens; the stamens are free, and generally of equal length, and are not joined together or to the corolla (see fig. 243, p. 168). The fruit, in most cases, is a many-seeded capsule (see fig. 437 [2]); in the genus *Fumaria* it is a small one-seeded drupe (see figs. 322 [1] and 322 [2], p. 427).

Fig. 436.—*Nelumbium speciosum*, the Indian Lotus, growing in a marsh, near Pekin (from a photograph).

In the Capparidaceæ, it is borne on a long stalk. The Resedaceæ are interesting, in that in many of them the ovary is open from the beginning, the stigmatic tissue being formed by the swollen lips. The Cruciferæ form a large and important family of over 200 genera. For systematic purposes they are divided into the following tribes:—Pleurorhizeæ, Notorhizeæ, Orthoploceæ, Spirolobeæ, and Diplocolobeæ. Annual or perennial herbs and suffrutices with the foliage-leaves in spirals, venation pinnate. Flowers in racemes, hermaphrodite, pseudo-hermaphrodite, actinomorphic and zygomorphic. Floral-leaves differentiated into calyx and corolla, each of which is composed of two 2-merous whorls. Petals free. Ovary free, superior. The carpels spring from below the end of the conical receptacle, and are of two kinds: the two lower carpels bear no ovules, but form valves, whilst the two

upper are transformed into ribs and form a framework to which the valves are applied. The two superior carpels are separated by a thin membrane, and bear the ovules in two rows (see p. 75). The andrœcium is composed of two short and four long stamens (see p. 292, fig. 284[8]). The pollen is adhesive. The fruit is a siliqua (see p. 75 and p. 431, fig. 325[15,16]). The seeds have no endosperm. The embryo is curved. The cotyledons and also the foliage-leaves and roots of most Cruciferæ contain pungent and oily substances, particularly Oil of Mustard, as is well known in the cases of the Mustard-plant, Water-cress, Garden-cress, Radish, and Horse-radish.

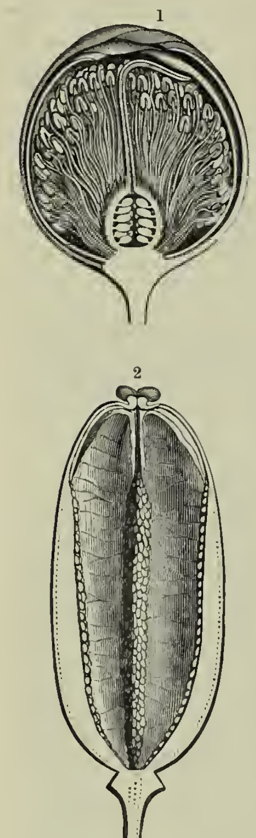


Fig. 437.—Parietales.

1 *Bixa Orellana* (Bixaceæ). Longitudinal section through a flower-bud which is about to open. 2 *Argemone Mexicana* (Papaveraceæ). Longitudinal section through the ovary. (Magnified.)

The Cruciferæ are distributed over the Northern Hemisphere. They occur in greatest variety in the steppe-districts of the Old World. The Mediterranean, Arctic, and Alpine floras also include large numbers of these plants. Amongst those Phanerogams which survive at the very confines of vegetation in the Arctic regions, and on mountains, are to be reckoned several Cruciferæ. No fossil remains are known.

The Sarraceniaceæ are marsh- and water-plants, and their leaves are adapted to the capture of insects (see vol. i. p. 143 *et seq.*), whilst the rest of the Parietales grow chiefly on rocky or sandy ground. The Parietales are distributed over the warm and temperate parts of the Old and the New World; the Cistaceæ belong especially to the flora of the Mediterranean. The only known instance of fossil remains is the fruit of a Poppy which was found in a deposit of the Tertiary Period. The number of extant species hitherto identified is about 3000.

Alliance LV.—**Malvales.**

Families: *Malvaceæ, Sterculiaceæ, Tiliaceæ.*

Flowers actinomorphic, parts in whorls of 5. Sepals free or connate, often valvate in bud. Stamens various, often united. Carpels 3 to indefinite, united. Placentation axile; seeds with endosperm. The Malvaceæ often possess an epi-calyx; fruit usually splitting into 1-seeded mericarps. They include the Mallows (*Malva*), Cotton-plants (*Gossypium*), Hollyhock (*Althæa*), &c. The Tiliaceæ are represented by the Linden (*Tilia*), and the Sterculiaceæ include *Theobroma Cacao*, from which chocolate is derived.

There are nearly 200 species in this alliance.

Alliance LVI.—Discifloræ.

Families: *Linaceæ, Erythroxylaceæ, Oxalidaceæ, Humiriaceæ, Malpighiaceæ, Zygophyllaceæ, Geraniaceæ, Balsamineæ, Tropæolaceæ, Rutaceæ, Auriantiaceæ, Diosmaceæ, Zanthoxylaceæ, Simarubaceæ, Ochnaceæ, Burseraceæ, Meliaceæ, Ilicineæ, Celastrineæ, Rhamnaceæ, Ampelideæ, Sapindaceæ, Acerineæ, Hippocastaneæ, Sabiaceæ, Terebinthaceæ.*

Annual and perennial herbs, shrubs, and trees, with simple and compound foliage-leaves. Flowers actinomorphic and zygomorphic, hermaphrodite, pseudo-hermaphrodite, monœcious and diœcious; arranged in varying types of inflorescence. Floral-leaves in two 4–5-merous whorls; the lower whorl a calyx, the upper a corolla. The gynæceum is composed of a whorl of carpels borne on a swollen disc. Ovary superior. Each carpel has a separate loculus. In Aurantiaceæ and Ampelideæ the carpels are completely united so as to form a single pistil; in Rutaceæ and Zygophyllaceæ they are united at the base and form a lobed ovary, whilst in Zanthoxylaceæ, Ochnaceæ, and Simarubaceæ, they are quite separate (see fig. 438 [6]). In Terebinthaceæ only one carpel is developed, but there are usually traces of suppressed carpels close to it. The ovules are in the inner angles of the loculi; in Aurantiaceæ, Rutaceæ, and Zygophyllaceæ their number exceeds two in each loculus, in the other families it is only 1–2. The stamens are arranged in 1–2 whorls, and number 4–5 in each whorl; they spring from the edge or from the surface of the floral receptacle, which is swollen and forms a ring round the ovary; their place of origin is always lower than the base of the ovary (see figs. 438 [2, 5, 7]). The pollen is adhesive. The fruit contains either few seeds or a single comparatively large seed.

The Disciforæ are in most instances woody plants, containing etherial oils and aromatic, resinous substances like turpentine. Amongst the Malpighiaceæ, Celastrineæ, and Ampelideæ are many lianes. The foliage-leaves are undivided in Erythroxylaceæ and Celastrineæ (see fig. 438 [1]), lobed in most Aceraceæ and Ampelideæ, and variously segmented and compounded in the other families (see fig. 438 [3]). The petals are usually small, and of a greenish-yellow colour. The filaments in Melianthaceæ and Aurantiaceæ are connate all together, or in groups. The fruits are extremely various. In Staphyleaceæ and Diosmaceæ they are follicles; in Celastraceæ and Rutaceæ, capsules (see fig. 325 [6], p. 431); in Zygophyllaceæ, Aceraceæ, and Malpighiaceæ, schizocarps; in the Tree of Heaven, of the family Simarubaceæ, winged achenes (samaras, see fig. 323 [7], p. 428); and in Ampelideæ and Aurantiaceæ, berries. The Disciforæ are distributed over the whole earth. The majority belong to the tropics, and several, *e.g.* Burseraceæ, Ochnaceæ, and Malpighiaceæ are exclusively tropical. The Diosmaceæ are confined to South Africa, the Rutaceæ to the districts of the Mediterranean and the Black Sea. Comparatively few species occur in the Northern Temperate Zone, or in corresponding situations on mountains. The Mountain Maple covers about the

Fig. 438.—Discifloræ.

[1] *Euonymus Europæus* (Family Celastrineæ), flowering branch. [2] Longitudinal section through a flower. [3] *Quassia amara* (Family Simarubaceæ), flowering branch. [4] Gynæceum and floral receptacle. [5] *Ochna* (Family Ochnaceæ), receptacle, gynæceum, and one stamen. [6] Fruit of same. [7] Longitudinal section through the flower of the Tree of Heaven (*Ailanthus*, family Simarubaceæ). (Partly after Baillon.)

same ground as the Beech, and, in the Central Alps, even extends beyond the upper limit of the Beech. Fossil remains are found in the Mesozoic and Tertiary strata. The number of known species now living is about 9000.

Alliance LVII.—Crateranthæ.

Families: *Leguminosæ, Rosaceæ, Saxifragaceæ, Escalloniaceæ, Cephalotaceæ, Francoaceæ, Crassulaceæ, Hydrangeaceæ, Ribesaceæ, Philadelphaceæ, Styracaceæ, Hamamelidaceæ, Rhamnaceæ.*

Annual and perennial herbs, shrubs, and trees. Flowers abundant; actinomorphic and zygomorphic; hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious. Floral-leaves in two 4–5-merous whorls, the lower whorl a calyx, the upper a corolla. Both whorls spring from the pitcher-shaped, bowl-shaped, or flat hypanthium, the petals always from the edge, the sepals, in part, also from the base of the hypanthium. In the last case the tube of the calyx is adnate to the external surface of the hypanthium. The gynæceum is in the middle of the hypanthium, and consists either of a single carpel with a unilocular ovary (see figs. 438*[1, 3, 4]), or of several separate unilocular carpels (see fig. 438*[2], and p. 74, fig. 208[2]), or of 2–many united carpels inclosing a multilocular ovary which may be adnate to the surrounding hypanthium at the base only, or from the base to the middle, or from the base to the top (see p. 74, fig. 208[4, 5, 6]). The ovules are situated on the ventral suture, and therefore in the inner angles of the loculi. The stamens spring from the edge of the hypanthium (see fig. 438*), and are in 1–2 whorls of 3–5 members each. The fruit is very various (pod, follicle, drupe, nut, berry, &c.), and the diversity in this respect affords the best means of distinguishing the numerous families belonging to this alliance. The hypanthium also varies considerably, and

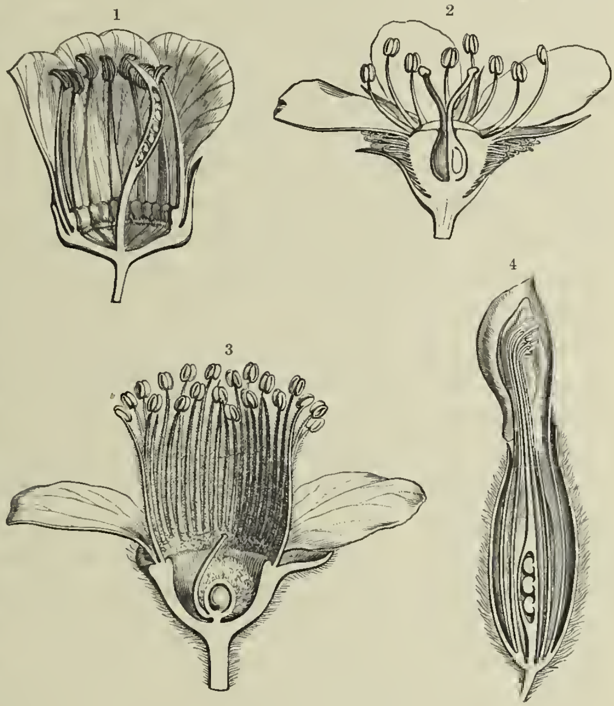


Fig. 438*.—Crateranthæ.

Longitudinal sections through the flowers of: [1] *Cadia varia* (Family Leguminosæ, division Cæsalpineæ). [2] *Agrimonia Eupatorium* (Family Rosaceæ, division Agrimoniaceæ). [3] *Chrysobalanus* (Family Rosaceæ, division Chrysobalanaceæ). [4] *Anthyllis Vulneraria* (Family Leguminosæ, division Papilionaceæ). (After Baillon.)

the families above enumerated may be placed in several groups according to the form of that structure. In the first group the hypanthium is short as compared with the floral-leaves, and dries up or detaches itself when the fruit is ripe (Papilionaceæ, Cæsalpineæ, Mimoseæ, Amygdaleæ, Rhamnaceæ); the pistil is simple. In the second group the hypanthium is flat, and bears the floral-leaves and stamens on its margin, and several separate unilocular carpels arranged in spirals in the middle of its surface; it does not fall off when the fruit ripens. In the third group the hypanthium undergoes further growth when the fruit ripens, and is converted into an envelope surrounding the nut-fruits, which have developed from the separate carpels in the interior of the pitcher-shaped cavity of the hypanthium (Agrimoneæ, Roseæ; see fig. 438*[2], and fig. 208[1, 2], p. 74). In the fourth group the multilocular pistil is adnate to the hypanthium which surrounds it entirely, and is converted into a fleshy pericarp (Pomaceæ; see fig. 208[4, 5, 6], p. 74). In the fifth group only the lower half of the 2-carpellary gynæceum is adnate to the hypanthium, so that its upper half projects above the hypanthium, which is clothed by the calyx-tube (some of the Saxifragaceæ). In the sixth and last group the short hypanthium is only adnate at the base to the multicarpellary, actinomorphic gynæceum (Crassulaceæ, Styracaceæ, &c.). These groups are by no means sharply defined, and the links connecting them are again described as special families. It is also worthy of note that honey-secreting tissues in the flowers exhibit extreme variety of form and position; sometimes they constitute a fleshy lining to the inner, *i.e.* the upper-surface of the hypanthium (several Dryadeæ), sometimes a swelling round the base of the ovary (several Saxifragaceæ), sometimes an annular ridge, or a group of separate wart-like glands, which are seated on the edge of the extremely short hypanthium, and are looked upon as metamorphosed stamens (Crassulaceæ).

Amongst Cæsalpineæ, Pomaceæ, and Hamamelidaceæ are many species of arboreal growth, and amongst Mimoseæ, Amygdaleæ, Roseæ, Spiræeæ, Rhamnaceæ, and Hydrangeaceæ are large numbers of shrubs and under-shrubs. The majority of the herbaceous plants of this alliance occur in the families of Papilionaceæ, Dryadeæ, Agrimoneæ, and Saxifragaceæ. The Cæsalpineæ include several climbing lianes, the Papilionaceæ afford numbers of instances of switch-shrubs, and the Mimoseæ exhibit many shrubs with phyllodes. Amongst the Saxifragaceæ and Crassulaceæ many species with thick leaves (see vol. i. p. 327) occur. *Cephalotus* is insectivorous (see vol. i. p. 131). Compound pinnate or digitate foliage-leaves occur especially in Rubeæ, Dryadeæ, Roseæ, Papilionaceæ, Cæsalpineæ, and Mimoseæ (see vol. i. p. 533), whilst entire foliage-leaves are found particularly in Amygdaleæ, Styracaceæ, Crassulaceæ, Philadelphaceæ, and Rhamnaceæ. The flowers of Papilionaceæ and Cæsalpineæ, and of some of the Saxifragaceæ and Chrysobalaneæ, are zygomorphic; those of the other families are actinomorphic. In some Mimoseæ, Crassulaceæ, and Styracaceæ the petals are connate at the base. Small, inconspicuous, greenish petals are exhibited by some Agrimoneæ, Dryadeæ, Saxifragaceæ, Crassulaceæ, and by many Hamamelidaceæ and Rhamnaceæ; but most of the species of the alliance Crateranthæ have brightly-coloured petals. Dusty pollen has

only been observed in a very few species (e.g. *Poterium*). In some Dryadaceæ and Chrysobalaneæ the style springs in a curious manner from the base of the ovary (see fig. 438*3). The fruit is a pod (legume) in Papilionaceæ, Cæsalpineæ, and Mimoseæ, and these three sub-families are hence often classed together by botanists under the name of Leguminosæ. The fruit of Amygdaleæ, Chrysobalaneæ and Rubeæ is a 1-stoned drupe, that of Rhamnaceæ a 3-stoned drupe. The Agrimoneæ and Dryadeæ are distinguished by small nut-like fruits, and the Spiræeæ, Saxifragaceæ, and Crassulaceæ have follicles which dehisce at the upper part of the ventral suture. In most of the families above enumerated the seeds contain no endosperm; on the other hand, the thick cotyledons are crammed with reserve materials, and several of these seeds are used as important articles of human food (*e.g.* beans, peas, lentils, &c.).

The Crateranthæ are distributed in all quarters of the globe and in all latitudes. Cæsalpineæ and Chrysobalaneæ belong chiefly to the tropics, whilst Dryadeæ and Saxifragaceæ live principally in the arctic regions and on high mountains. The Papilionaceæ are found most abundantly in the area of the Mediterranean flora and in the steppes in the south-west of Asia. More than 800 species of the genus *Astragalus* alone are known to exist in the last-mentioned districts. The Mimoseæ, especially the species of the genus *Acacia*, are represented in Africa and Australia by many characteristic forms. Roseæ and Rubeæ, *e.g.* the genera *Rosa* and *Rubus*, occur in an astonishing variety of species in Central Europe, whilst the Spiræeæ and Amygdaleæ are in like abundance in the west of Asia. Crassulaceæ are most abundant at the Cape and in Mexico, but they are also represented by a great number of species of the genus *Sempervivum* in the mountainous parts of Southern Europe. *Rhodiola rosea*, which belongs to this family, occurs in the arctic flora, and *Sedum repens* is found in the Alps at a height of 3000 metres above the sea. Of the Saxifragaceæ, *Saxifraga oppositifolia* reaches the furthest north, it having been met with at the northernmost spot hitherto visited in Franz Joseph's Land, at 81° N. Lat. In the Central Alps this Saxifrage is found at an elevation of 3160 metres. Fossil remains of Rosaceæ, Leguminosæ, and Rhamnaceæ have been identified in the deposits of the Tertiary Period. The number of extant species hitherto discovered amounts to about 10,000.

Alliance LVIII.—**Myrtales.**

Families: *Myrtaceæ, Granataceæ, Onagraceæ.*

Annual and perennial herbs, shrubs, and trees, with entire foliage-leaves. Venation consisting of a main axial strand, with sinuous lateral strands branching pinnately from it. Flowers hermaphrodite, actinomorphic or zygomorphic. The floral-leaves spring from an annular or tubular hypanthium, which is fused with the inferior ovary; they are differentiated into calyx and corolla, each of which consists of a 2–6-merous whorl. The stamens are in 1, 2, or more whorls of 2–6 members

each, and spring from the fleshy annular or tubular hypanthium which rises up above the ovary. The fruit is baccate, drupaceous, or capsular.

The Granataceæ and Onagraceæ contain watery juices, whilst the species belonging to the other families are more or less rich in aromatic substances and etherial oils. Several are used as spices. Allspice is derived from *Pimenta officinalis,* and cloves are prepared from the flower-buds of *Eugenia caryophyllata.* The Circæeæ are small and delicate herbs, the Chamælauceæ are dwarf shrubs; whilst the genus *Eucalyptus* of the family Myrtaceæ includes several species which are amongst the highest trees in the world (see vol. i. p. 723). The flower in *Circæa* exhibits two sepals, two petals, and two stamens in order (see fig. 261[8], p. 236). In *Œnothera* and *Epilobium* the calyx and the corolla are composed of one 4-partite whorl each, and the andrœcium of 2 such whorls (see fig. 281, p. 282, and fig. 300, p. 354). In *Eucalyptus, Myrtus,* and many other genera the number of stamens amounts to over

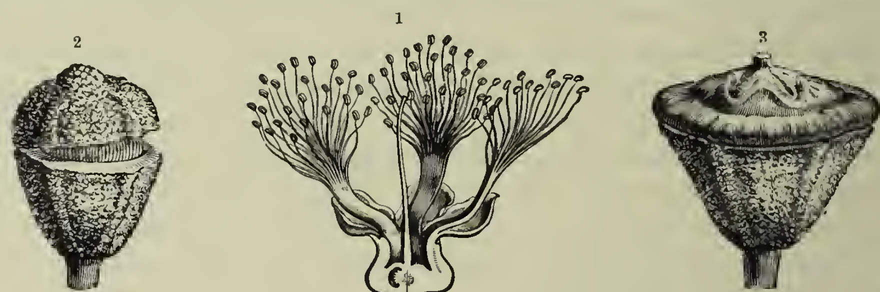


Fig. 439.—Myrtales.

[1] *Melaleuca.* Longitudinal section through the flower. [2] Flower-bud of *Eucalyptus globulus*; the connate sepals are detached from the receptacle as a lid when the bud opens. [3] Fruit of *Eucalyptus globulus.* (After Baillon.)

100; in *Melaleuca* (see fig. 284[4], p. 292) the stamens are coherent in bunches. Where the petals are suppressed, the filiform filaments are white or bright red and yellow. In the Fuchsias the sepals are coloured like petals; in some species of the genus *Eucalyptus* the sepals, which are joined together so as to form a lid, become detached from the floral receptacle before the flower opens. This remarkable phenomenon is shown in fig. 439[2]. The hypanthium which invests the ovary exhibits every possible transition in form, from a shallow saucer to a long tube (see fig. 266, p. 247). The ovary is in several families divided by septa, composed of tissue pertaining to the receptacle, which extend from the central column to the wall of the ovary. In Granataceæ (*Punica Granatum*) the ovary is in addition divided by a plate of tissue into an upper and a lower story, and placentas are developed in the chambers of both stories. The fruits of several Lecythidaceæ, *e.g.* those of *Lecythis,* open with a lid; those of *Eucalyptus* are in the form of hard woody capsules, which dehisce at the top by means of valves, pores, or slits (see fig. 439[3]). The fruits of *Circæa* are indehiscent; those of *Epilobium,* &c., are capsular, and open by valves. Many Myrtaceæ and the Fuchsias have baccate fruits. The fruit of the Pomegranate (*Punica Granatum*) resembles an apple. The seeds of *Bertholletia excelsa* of the family Lecythidaceæ are known as Brazil nuts, and have a coat as hard as stone;

those of the Pomegranate have a fleshy coat, and those of *Epilobium* are furnished with hairs. The Myrtales are distributed over all quarters of the globe. The Chamælauceæ and Leptospermaceæ are natives of Australia and the islands of the Pacific Ocean. Several species of this family help to form Australian bush, whilst others, especially species of the genus *Eucalyptus,* constitute entire forests (see Plate XVI.). The Lecythidaceæ grow chiefly in South America. The Myrtaceæ are most abundant in America, and occur also in Asia and Africa. Europe only possesses one species, *Myrtus communis,* which belongs to the Mediterranean Flora. The Fuchsias are indigenous to Central and South America. The Epilobiums and

Fig. 440.—Melastomaceæ.

Melastoma Malabathricum. (After Baillon.)

Circæas live principally in the North Temperate Zone, and some species of the genus *Epilobium* occur in the arctic regions and on mountain heights. Fossil remains of Myrtaceæ and Granataceæ have been found in the strata of the Tertiary Period. The number of species ascertained to exist at the present day is about 2500.

Alliance LIX.—Melastomales.

Family: *Melastomaceæ.*

Perennial herbs, shrubs, and trees, with opposite or whorled foliage-leaves. Leaves entire, with 3–11 curved ribs connected by transverse anastomoses (see fig. 440). Flowers hermaphrodite or pseudo-hermaphrodite; slightly zygomorphic. Floral-leaves differentiated into calyx and corolla. The bowl-shaped or tubular

receptacle is covered externally by the tube of the 4–6-sepalous calyx, is surmounted by the segments of the calyx-limb, and bears upon it the 4–6 petals which alternate with those segments. The gynæceum is composed of 3–8 connate carpels. The 3–8-locular ovary is adnate to the hollowed receptacle at the base only, or from the base to the middle, or from the base to the top. An axis rises up in the middle of the ovary and bears the placentas, which project into the separate loculi. The andrœcium is composed of 1–2 whorls of 4–5 stamens each. At the base of each anther is a spur-like appendage; dehiscence is apical by 1 or 2 small holes (see fig. 216[13], p. 91). The pollen is powdery. The fruit is a berry or a capsule which dehisces by valves. The seeds contain no endosperm.

The Melastomales belong chiefly to tropical America. Fossil remains have not been identified with certainty. The number of species ascertained to exist at the present time is about 2000.

Alliance LX.—**Lythrales.**

Families: *Lythraceæ*, *Cupheaceæ*, and *Lagerstrœmiaceæ*.

Annual or perennial herbs, shrubs, and trees with opposite or whorled foliage-leaves. Laminæ entire, with pinnate venation. Flowers hermaphrodite, actinomorphic or zygomorphic, with calyx and corolla. The cup-shaped or tubular receptacle is covered externally by the tube of the 3–16-sepalous calyx, the segments of which project beyond it and alternate with the 3–16 petals which are borne upon the receptacle. The gynæceum is composed of 2–6 connate carpels. The 2–6-locular ovary is free, and is situated at the bottom of the hollow receptacle. An axial column rises up in the middle of the ovary and bears the placentas, which project into the separate loculi. The andrœcium is composed of 1–2 whorls of 3–16 stamens each. The anthers have no appendages, and dehisce by longitudinal slits. The pollen is adhesive. The fruit is a capsule coated by the cup-shaped receptacle. The seeds contain no endosperm.

The Lythrales are distributed in all quarters of the globe. They exhibit greatest variety in tropical America. In the North Temperate Zone they are represented by the genera *Lythrum*, *Peplis*, and *Didiplis*. No fossil remains are known. The number of identified species now living is about 400.

Alliance LXI.—**Hygrobiæ.**

Families: *Hippuridaceæ*, *Callitrichaceæ*, *Myriophyllaceæ*, *Gunneraceæ*, *Trapaceæ*.

Herbs and under-shrubs living in water or in wet places. Flowers hermaphrodite, pseudo-hermaphrodite, monœcious, and diœcious; actinomorphic. Floral-leaves inconspicuous, in 1–2 whorls of 2–4 leaves each. Gynæceum of one carpel or 2–4 connate carpels. The under half or the whole of the 1–4-locular ovary is adnate to the sepals, which cohere so as to form a cup. Each loculus contains one ovule in its inner angle. The andrœcium is composed of 1–8 stamens. The fruit is

a schizocarp (*Callitriche*; see p. 427, figs. 322 [3] and 322 [4]) or a drupe covered with a thin coat of pulp; it becomes detached from the receptacle. In the Water Chestnut (*Trapa natans*; see vol. i. p. 607, fig. 144) the two whorls of two sepals each which are adnate to the ovary become a part of the fruit, and their apices project in the form of four stiff points. The Hygrobiæ are distributed in every quarter of the globe, but belong especially to the North Temperate Zone. The Gunneraceæ inhabit the Southern Hemisphere. Fossil remains of a plant resembling *Myriophyllum* have been found in strata of the Tertiary Period. The number of extant species known is about 100.

Alliance LXII.—**Passiflorales.**

Families: *Passifloraceæ, Loasaceæ, Datiscaceæ, Samydaceæ, Turneraceæ, Papayaceæ.*

Annual or perennial herbs, shrubs, and trees, with palmately-lobed foliage-leaves. Venation palmate (radiating). Flowers hermaphrodite or pseudo-hermaphrodite, and diœcious; actinomorphic. The floral-leaves spring from a cup-shaped hypanthium in one or two 4–5-merous whorls. The gynæceum is composed of 3 connate carpels. The unilocular ovary is free, and is raised upon a more or less elongated stalk from the bottom of the receptacle, or else it is sessile and adnate to the cup-shaped receptacle either half-way from the base or from base to top. The ovules are borne upon three placentas which project in the form of cushions from the internal wall of the ovary. The andrœcium is composed of 4–5 stamens which spring from the edge of the cup-shaped hypanthium. The fruit is a berry or a capsule opening by valves. The seeds contain a fleshy endosperm, in which is imbedded a straight embryo.

The Datiscaceæ have a sepaloid perianth. In the Loasaceæ and Passifloraceæ the floral-leaves are in two whorls, both of which are petaloid. In the Passifloraceæ a many-membered corona is inserted between the andrœcium and the petals. The Passiflorales belong chiefly to tropical America. Fossil remains have not been identified with certainty. The number of extant species known is about 700.

Alliance LXIII.—**Pepones.**

Families: *Cucurbitaceæ* and *Begoniaceæ.*

Annual and perennial herbs and under-shrubs (suffrutices). Venation of the foliage-leaves radiating (palmate). Flowers solitary or in cymes; actinomorphic; pseudo-hermaphrodite, monœcious and diœcious. The uppermost part of the receptacle, which is deeply hollowed, is developed as a hypanthium, and from it spring the floral-leaves in 1–2 whorls of 2–5 segments each. When two whorls are present they are either both petaloid in colour or the under whorl is a calyx and the upper a corolla. The petals are either free or partially coherent. The ovary is inferior. The ovules are borne on thick pads which are split in two longitudinally,

and project into the middle of the ovary. The andrœcium is composed of 5 or many stamens which spring from the hypanthium, and are joined at the base to the corolla. The fruit is baccate or capsular. The seeds contain no endosperm.

The Cucurbitaceæ have symmetrical foliage-leaves—no stipules, but often tendrils (see vol. i. p. 696, fig. 165); the Begoniaceæ have oblique, unsymmetrical laminæ, large lacerated stipules, and no tendrils (see vol. i. p. 420, fig. 110 [1]). The whorls of floral-leaves are 5-merous in Cucurbitaceæ; in Begoniaceæ the floral-leaves of the female flowers are arranged in two whorls of 3–5 segments each, and those of the male flowers in two whorls of 2–5 segments each. Three winged ridges project from the inferior ovary in Begoniaceæ. The stalks of the ovules of Cucurbitaceæ fill the cavity of the ovary so completely that only small interstices are left between them. In many Cucurbitaceæ these stalks are converted when the seeds ripen into a succulent mass (*e.g.* in cucumbers, melons, and gourds). In Begoniaceæ also they project from the walls into the middle of the ovary, and the latter looks in consequence as if it were divided into loculi. The andrœcium exhibits great diversity. In some Cucurbitaceæ the five stamens are free; in others they are partially united, and in a third group they are all completely fused together into a column. In Begoniaceæ, also, the stamens are connate and form a column. In many cases the anthers are sinuous, and in the genus (*Cyclanthera*) there is a continuous anther all round the column. The Pepones are mainly tropical plants. The Begoniaceæ grow especially in the tropical forests of America, where they are not infrequently epiphytic. There is still some doubt as to the place of origin of Melons, Gourds, and Cucumbers. The alliance is represented by the Squirting Cucumber (*Elaterium*) in the South of Europe, and by Bryony (*Bryonia*) in Central and Northern Europe. No fossil remains have been discovered. The number of extant species hitherto identified is about 1100.

Alliance LXIV.—**Cactales.**

Families: *Opuntiaceæ* and *Cactaceæ.*

Perennial plants, whose stems are much swollen or flattened. Flowers solitary; actinomorphic or zygomorphic; hermaphrodite. The ovary consists of a hollow, cup-shaped floral receptacle, from the inner wall of which spring filiform stalks bearing the ovules (see fig. 209 [1, 2], p. 77). The external surface of the receptacle is clothed by floral-leaves arranged in a spiral; the lower leaves are small and inconspicuous, the upper petaloid and brightly coloured (see figs. 441 [1, 2, 3, 4, 5]). Inside the upper tubular prolongation of the receptacle are crowds of stamens arranged spirally. The pollen is adhesive. The fruit is unilocular and succulent (see fig. 441 [2]). The seeds contain no endosperm.

The genus *Pereskia* alone exhibits thick, green foliage-leaves; in the other genera the leaves are replaced by small caducous scales or thorns, and assimilation is effected by means of the green cortical tissue of the swollen stems (see vol. i. pp. 327 and 440). The species of *Rhipsalis* and *Phyllocactus*, which are epiphytic

on the branches of old trees, have much-branched and segmented phylloclades, which often hang in curves; the segments of the stem in Opuntias are laterally compressed, and more or less discoid (see vol. i. Plate IV.). The cylindrical stems of the Queen of Night (*Cereus nycticalus*, vol. i. Plate VII., in foreground) are prismatic, and climb up rocks and the bark of trees by means of clinging roots. Other species of *Cereus*, such as *Cereus giganteus*, which grows to a height of 20 metres, possess erect columnar stems (Plate VII., left hand, middle distance). Another set of *Cereus*-species, including the many forms of *Mammillaria, Melocactus, Echinocactus*, and *Echinopsis*, are spherical or truncate; they are covered either with papillæ, each of which is crowned by a bunch of prickles (see fig. 441 [3]), or

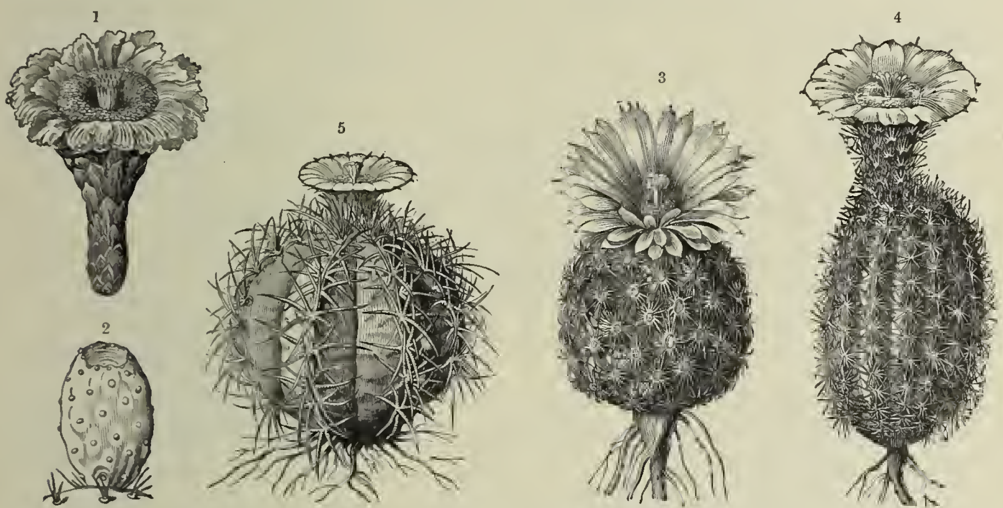


Fig. 441.—Cactaceæ.

[1] Flower. [2] Fruit of *Cereus giganteus*. [3] *Mammillaria pectinata*. [4] *Cereus dasyacanthus*. [5] *Echinocactus horizontalis*. All the figures reduced.

with tubercles, which coalesce into crests and ribs (see figs. 441 [4] and 441 [5]). The Cactuses are natives of the New World, and inhabit regions where a short, rainy season is followed by a prolonged period of drought. The largest number of species is found in Mexico. Some species also occur at high elevations in the Andes. No fossil remains are known. The number of species ascertained to exist at the present time is about 1300

Alliance LXV.—**Ficoidales.**

Families: *Portulaceæ, Molluginaceæ, Ficoidaceæ, Mesembryanthemaceæ.*

Annual and perennial herbs and under-shrubs, with entire fleshy foliage-leaves. Flowers solitary or in fascicles and glomerules; actinomorphic, hermaphrodite. The floral-leaves free or else connate at the base; in one, two, or several 2–5-merous whorls. Either all the floral-leaves, or only those of the lowest whorl, are sepaloid; in the latter case, the upper whorl or whorls are petaloid. The

gynæceum is composed of 3, 5, 8 or more connate carpels. The ovary is adnate to the bowl-shaped receptacle at the base only or as regards the lower half of its surface, or from the base to the top; it is crowned by a radiating stigma of 3–10 rays, and is uni- or multi-locular. A column rises up in the middle of the ovary, and bears the ovules. In the case of multilocular ovaries, the ovules are borne on ridges and strands which project from this column into the loculi. The andrœcium is composed of one or several whorls of 3–10 stamens each. The anthers have no spurs, and they dehisce by longitudinal slits. The pollen is adhesive. The fruit is a capsule or an achene. The seeds contain a mealy albumen and a curved embryo.

The Ficoidales chiefly inhabit dry localities. Only a few species (e.g. *Montia fontana*) live in water and on marshy soil. They are distributed all over the globe. Most of the Portulaceæ belong to South America and the Cape. The Mesembryanthemaceæ are developed in extraordinary variety in South Africa. There are over 300 species of the genus *Mesembryanthemum* alone at the Cape. No fossil remains are known. The number of extant species hitherto identified is about 500.

Alliance LXVI.—Umbellales.

Families: *Cornaceæ, Araliaceæ,* and *Umbelliferæ.*

Annual or perennial herbs, shrubs, and trees which flower profusely. Flowers in capitula, umbels, and cymes. Floral-leaves differentiated into calyx and corolla. The calyx 4–5 sepalous, with its tube clothing the inferior ovary and the limb represented by 4–5 small teeth, which surround the top of the ovary. The corolla is likewise 4–5 petalous, the petals free and alternating with the sepals. The gynæceum is composed of a whorl of connate carpels; ovary inferior, 2–5 locular. Every loculus corresponds to a carpel, and contains a single ovule, which is suspended near the upper end of the loculus (see fig. 442 [4]). On the top of the ovary is a glandular disc, which secretes honey (see figs. 442 [2, 4, 7]). The andrœcium consists of a whorl of 4–5 stamens. The stamens are quite separate, and stand in a circle round the honey-secreting disc. The fruit in Umbelliferæ is a schizocarp (see p. 427, fig. 322 [5, 6, 7] and fig. 442 [3]), in Cornaceæ and Araliaceæ a berry or drupe. The seed contains an abundant endosperm, in which the embryo is imbedded.

The Cornaceæ are for the most part woody plants, with entire, opposite foliage-leaves, possessing a venation of arched strands (see p. 231, fig. 260 and vol. i. p. 630). The Araliaceæ, of which the Ivy (*Hedera Helix*, see vol. i. p. 703, fig. 167) may be taken as a type, are woody plants with climbing roots, or shrubs and herbs with radiately-veined foliage, and the Umbelliferæ, which are very rich in aromatic substances, oils, and resins, are for the most part herbs whose stems in many species reach a length of 3–4 metres, as, for instance, in *Ferula communis* and *Euryangium Sumbul.* The foliage-leaves of Umbelliferæ are usually much divided (see fig. 442[1]), those of *Hydrocotyle vulgaris*, a plant which lives in swamps, are peltate (see

fig. 442[5]). The calyx, corolla, and andrœcium are 4-merous in Cornaceæ, 5-merous in Umbelliferæ and Araliaceæ (see figs. 442[2] and 442[6], and p. 289, fig. 283[4]). The Umbellales belong chiefly to the North Temperate Zone, but the Araliaceæ are

Fig. 442.—Umbellales.

[1] *Heracleum Sphondylium* (Family Umbelliferæ), flowering plant. [2] Single flower. [3] Fruit. [4] Longitudinal section through the flower of *Eryngium maritimum* (Family Umbelliferæ). [5] *Hydrocotyle vulgaris* (Family Umbelliferæ), entire plant. [6] *Cornus mas* (Family Cornaceæ), inflorescence. [7] Longitudinal section through a flower. [8] Fruit. [1] reduced; [2], [3], [4], [5], [6], [7], and [8] magnified. (After Baillon.)

also represented by a number of species in the Tropics. Several of the Umbelliferæ are natives of the arctic area of vegetation and of alpine regions. *Gaya simplex* occurs in the Central Alps as high as 2600 metres above the sea-level. Fossil remains, belonging chiefly to the families of Araliaceæ and Cornaceæ, have been

found in the deposits of the Mesozoic and Tertiary Periods. The number of extant species identified hitherto amounts to about 1800.

4.—THE DISTRIBUTION OF SPECIES.

Distribution of Species by Offshoots.—Distribution of Species by Fruits and Seeds.—Limits of Distribution.—Plant-Communities and Floras.

THE DISTRIBUTION OF SPECIES BY OFFSHOOTS.

When the dreaded Dry-rot spreads unhindered over the surfaces of wooden beams, in a dark, damp cellar, its mycelium presents quite a strange appearance. Grouped in a circle around a dark centre of dead, disintegrating, and crumbling wood are a number of white spots, joined by indistinct lines to a centre. But this was not always the case. That which now forms the dead and crumbling centre was formerly the seat of the first development of the mycelium, then composed of a coherent network of mycelial threads and appearing to the naked eye as a single rounded white spot. The mycelial threads then crept out like rays all round the periphery, and as the white spot increased in diameter its centre became proportionately dark. The mycelial threads forsook their first settlement; they died off, and the wood they had destroyed then appeared merely as the dark centre of a white ring. In consequence of its continual widening the ring at length becomes segregated into stars, and is gradually transformed into a wreath of isolated mycelia, or, in other words, a group of separate but distinct mycelial spots arranged in a circle arises from a single mycelium in consequence of its radiating method of growth.

The mycelium of Gasteromycetes, of many Fungi allied to Morels, and especially of many Agarics growing in the forest mould or in meadow humus, also exhibit under favourable conditions this ring and wreath formation. Although it is not possible to see the subterranean growth directly, its results are readily recognizable, since the receptacles rise above the ground from the separate portions of mycelium and indicate their distribution; these receptacles occur in regular circles, and when their colour contrasts with the surroundings they are especially conspicuous. Rings of this kind are shown in fig. 443 formed by the Ascomycete *Spathularia flavida*. The subterranean mycelium of this Fungus exercises no injurious influence on plants in the immediate neighbourhood—at any rate, the mosses, grasses, and weeds which compose the carpet of the meadow round about show no sign of weakness, but are equally fresh and luxuriant within and without the rings. But it is not so in meadows where Agarics of the genus *Marasmius* and others have settled. The meadow-plants whose roots and root-stocks have been penetrated by their mycelia die off, and the places can be easily recognized by the withering and discoloration of their green aërial parts. On first looking at these spots one might easily suppose that the foundations of old circular walls were lying close under the turf which had

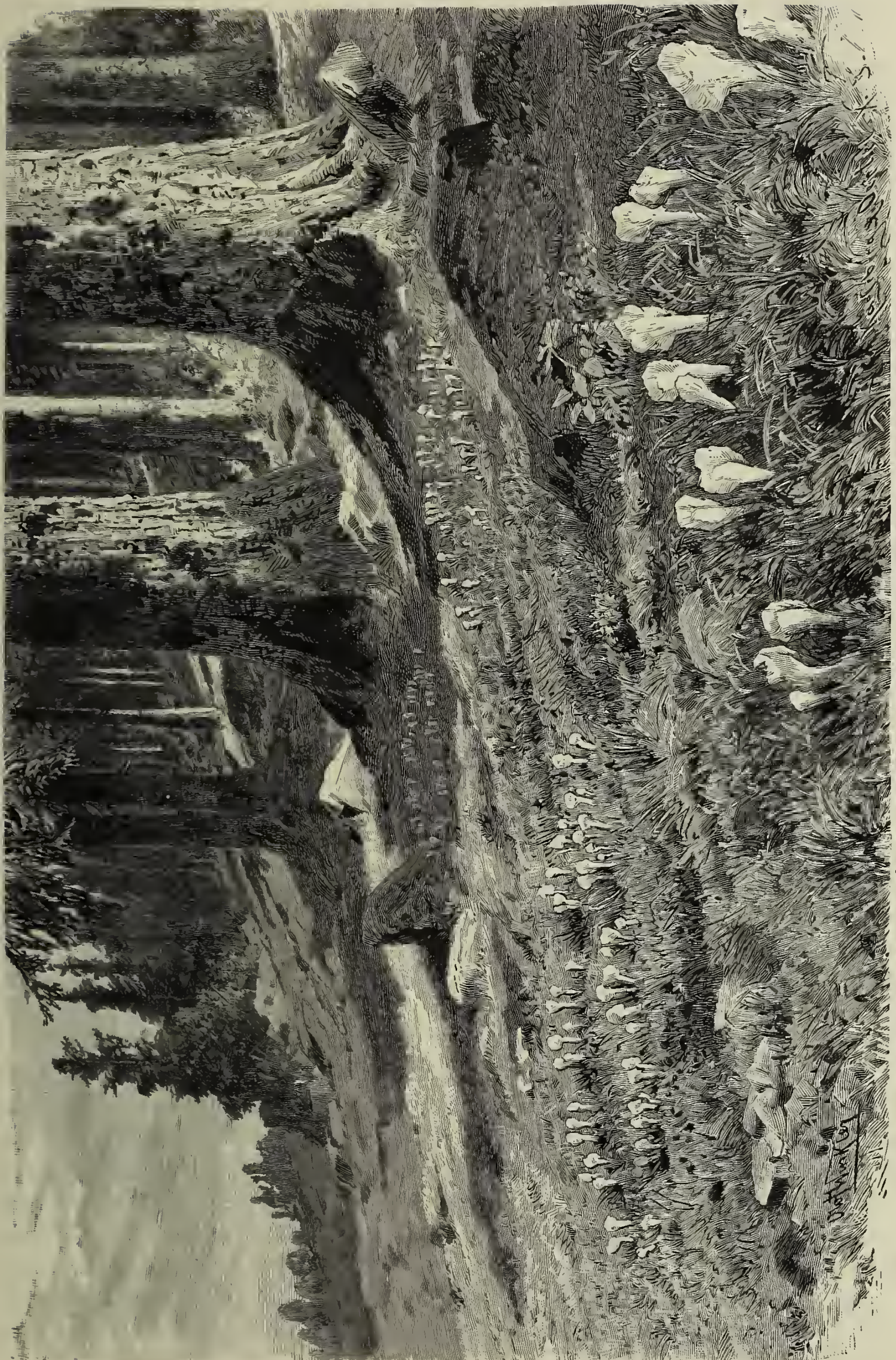


Fig. 443.—Fairy Rings in a meadow near Trins in the Tyrol, formed by the ascomycetous fungus *Spathularia flavida*.

in consequence dried up above the stones; that this is not so may be readily proved by digging, and this shows us at the same time that the humus and roots in these places are quite riddled and wrapped round by the mycelium of the Fungi named. The brown and grey ring- and crescent-shaped stripes show up most clearly on meadows because a parallel stripe of a specially vivid green is usually seen close to them. The reason of this is that, after two years, new plants develop in all those places which were formerly occupied by the mycelium, and have been abandoned by it in its centrifugal growth. Strangely enough, these plants are not the same species which were killed there in the previous year, but are herbs and grasses which find a suitable nourishing soil in the places which have lain waste for 1–2 years. The roots and root-stocks of the plants killed by the mycelium have meanwhile decomposed, together with the remains of the mycelium and the receptacles of the Fungi. The soil is thus manured, and plants which usually settle on fallow ground grow there in abundance. They raise luxuriant stems and leaves, and thus is produced on the inner side of each bare stripe a parallel one of a bright green colour.

This phenomenon has long been noticed by country people, particularly in regions where pastures are an important feature. It is associated with the influence of ghosts, witches, and elves; hence the name of fairy rings. In Upper Austria these bare dry spots are regarded as the rendezvous of the witches, and Walpurgis Night (1st May) is supposed to be the time when they are produced. In the Tyrol and other primitive countries the most varied superstitions are held to account for these curious stripes and patches.

Fairy rings are sometimes formed by plants with underground rhizomes and runners, although not so frequently as by the subterranean mycelia of the Fungi named. Some Composites (for example *Petasites niveus* and *P. officinalis*, *Arnica Chamissonis*, *Achillea Millefolium*), Labiates (*Betonica grandiflora*, *Mentha alpigena*), Irises (*Iris arenaria* and *I. Pallasii*), Grasses, Sedges, and Rushes (*Hierochloa borealis*, *Sesleria cœrulea*, *Carex Schreberi*, *Juncus trifidus*), under suitable conditions of soil form ring-shaped and garland-like colonies independently of Fungi. The mode of growth in these plants is like that of the Dry-rot. Young plants grow up with closely crowded shoots; these then spread out on all sides, and the connecting links die off simultaneously. In this way the original settlement is left a bare patch with dried remains surrounded by a circle of distinct and vigorous offshoots. Though shoots are very numerous they still stand close together even after they have severed connection, and if their annual growth is but slight it is some time before an actual ring is formed. It is in this case, however, the more striking, so that even a casual passer-by cannot fail to notice it. This happens principally in the above-named Grass-like plants, and among them especially in *Sesleria cœrulea*, which has attained a certain celebrity in Sweden as the ring-forming plant. It is there popularly termed *elf dansar*, and legend has it that the elves are especially fond of holding their nightly dances on places where rings of this Grass have been formed.

Of course good rings are only produced by the plants named if the foremost buds produced by the subterranean internodes, *i.e.* those which form the terminations of the radiating stock or rhizome, undergo further development, while the intervening ones perish. This may not be the case under certain conditions, particularly if the growth of the terminal buds is retarded or stopped. For this reason fairy rings are formed much less frequently on stony, uneven ground than on flat homogeneous soils; and the best lands for this kind of fairy rings are pastures stretching over a mountain plateau, or the even floor of a valley.

If specimens of the plants here described are planted on smooth ground, in good soil in a garden, in places where there is no obstacle to their spreading, they will form the rings and wreaths in question within a few years. But in spite of this, very few people are ever able to witness this interesting spectacle in gardens, because gardeners will not leave the rings alone, regarding the bare patch in the centre as unsightly and that the existence of a ring is a slur upon their craftsmanship. I remember noticing this many years ago in the Botanic Gardens at Innsbruck. The perennial plants were cultivated in certain beds close together, and to each species was allotted a limited amount of space. When the spring came round the gardener dug up the periphery of the circle, and planted it in the centre, to catch the escaping plants, as he put it. In the spots where *Mentha alpigena* had stood the previous year only a few withered stumps were to be seen, and not a single living shoot could be found. But shoots with their tops above the ground could be seen in a circle in the neighbouring beds, and also in the paths between the beds all round the space set apart for this species of Mint. These shoots were ruthlessly dug up and planted again in the forsaken spot. Every year or every second year this capturing of the fugitives was repeated, not only in the case of the Mint, but in many other instances, as, for example, *Achillea asplenifolia* and *A. tomentosa*, *Betonica grandiflora*, and *Lysimachia thyrsiflora*.

Amongst aërial-sprouting plants which form rings and wreaths may be numbered the majority of Moulds, Lichens, and Mosses. The Mould, *Penicillium glaucum*, which settles on the fruit rind of oranges, apples, and pears, at first makes its appearance as a mere point, but later as a circular spot, and finally as a distinct ring surrounding a brown and rotten centre.

The most striking of the ring-forming Lichens are those which stand out from their substratum on account of their colour. Most noticeable in this respect are the white *Parmelia conspersa*, which contrasts with the dark slate rock, and the saffron-yellow species *Amphiloma callopisma* and *Gasparrinia elegans*. The gelatinous Lichens, dark olive-green normally, but black when dried, especially *Collema multifidum* and *C. pulposum*, often form such regular wreaths on a light background of limestone that they look as if they had been drawn with compasses, and the tiny yellowish-red *Physcia cirrochroa* has a particularly elegant appearance when it has radiated out from the hundreds of spots where it established itself on the flat surfaces of a steep calcareous rock. One might almost think that the small orange wreaths had been painted in with a brush. They also remind one of the fleecy

clouds in the evening sky, whose edges are reddened with the rays of the setting sun; and if I am not mistaken, this Lichen has obtained its name on account of this resemblance.

The chief Liverworts and Mosses which form rings and wreaths when they grow on the flat surfaces of steep rock-faces and on the bark of old tree-trunks, are *Frullania dilatata, Radula complanata, Amblystegium serpens, Anomodon viticulosus*, and *Hypnum Halleri*. When they first settle they are scarcely noticeable on account of their minuteness, but they spread very rapidly, their firmly adherent stems forking and radiating out in all directions, the whole plant at a little distance now forming a greenish-yellow spot of circular outline. While growth proceeds in this way round the periphery of the Moss-plant, covering the rock or bark like a carpet by the multiplication of its outer forked branches, the older parts near the original place of settlement become dry, disintegrate, and are blown away like dust by the wind, the naked rock or bare bark thus again coming into view. In this way 5, 10, or 20 new Moss-plants are derived from the original one, and stand in a circle round the bare centre. This circle widens from year to year, until at last it is interrupted by gaps, and then 20 or more specimens of the Moss are seen adhering to the substratum arranged in a circle more than a span from the original settling place.

In order that the ring or wreath arrangement of the offshoots above described should obtain, it is necessary that the original plant should dry up and decompose, and that the shoots which radiate from it should also die off behind in proportion as their growing points travel away from the centre of the settlement, and, finally, that no new ring-forming species should establish itself, or spread on the dead centre for a considerable time. These conditions are only comparatively rarely fulfilled, and this is the reason that ring and wreath formations are relatively so scarce.

It happens much more frequently that the plant forming the starting-point of a colony, after it has sent out creeping threads of cells, runners, shoots, and the like in all directions, does not itself perish, but remains living and active in the centre of its separated shoots, even sending out new shoots year after year. In the same way the separated shoots repeat the parent-method of growth, *i.e.* they send out shoots in all directions like the mother-plant, though perhaps less regularly, and thus of necessity some of the young shoots come back to the bare centre and settle down where the mother-plant originally stood. The following phenomenon may also be observed: A plant gives off annually a pair of horizontal shoots on one side only, let us say on the south; their buds in the course of time become independent plants, and each again sends out a few horizontal shoots towards the south. In a few years' time these offshoots give rise to 20–30 plants, which are more or less distant from the starting-point, according to the length of the shoots. In all these cases the offshoots are not arranged in a ring or wreath round an empty centre, but in lines or clusters.

Like the ring- and wreath-forming colonies, the offshoots, forming lines and clusters, may be underground or aërial. The receptacles of many Fungi emerge in a

clearly lineal arrangement from the mycelial threads running below the surface of the ground and in dead, rotten tree-trunks. Some Mosses form colonies in very regular lines from their rhizoids and horizontal underground protonemas. The most conspicuous, however, is the line formation produced by roots which run horizontally below the soil. The Aspen (*Populus tremula*), the Sea Buckthorn (*Hippophae rhamnoides*), *Lycium barbarum*, the Raspberry (*Rubus Idœus*), the Dwarf Elder (*Sambucus Ebulus*), *Asclepias Cornuti*, various species of *Linaria* and *Euphorbia*, and numerous other plants (*cf.* p. 27) produce special horizontal underground roots, which give off buds towards the upper side. The shoots arising from these buds form separate independent plants after the root which formed them has died away. Obviously the plants follow the direction of the roots, and are arranged in rows. Even for years afterwards the line-like arrangement of the individuals in such colonies can still be recognized. When the bud-forming roots are of considerable length, the terminal offshoots are sometimes situated at some distance from the mother-plant. I saw single offshoots from the root of an Aspen push up through the ground 30 paces from the woody parent stem. Stems of *Asclepias Cornuti* spring up from the thick horizontal roots deep under the ground, at intervals of about 40 cm., and in them also can the linear arrangement be sometimes very clearly seen. When the individual offshoots in their turn give rise to horizontal roots, the line-formation is lost sight of more and more, and a scattered group spread over a wide area is the result. Sometimes the older portions of the colony die off completely, and as the individuals in one direction disappear, those in the other grow more luxuriantly. One might almost suppose the whole group to have taken a few steps forwards. This phenomenon can be seen particularly well in Raspberry bushes. On suitable soil a group of Raspberries will move about 2 paces every year, and therefore, after 10 years, they may have moved about 20 paces. If Raspberry bushes are planted near an inclosed piece of ground along a fence or hedge, it may happen that ten years later not a single one can be seen in the original place, while on the other side of the fence, in the neighbouring piece of ground, quite an assemblage of Raspberry plants has come into existence.

The clustered or linear colonies which spring from underground tubers have the following very simple history. After a tuber has been fully formed on the underground shoot of a plant the slender bridge-like connections which have hitherto served for the conduction of food break down by the decay and decomposition of their tissues. The new tubers thus separated from the mother-plant send out stems from their buds, after the necessary period of rest these push up above the ground and also give rise to new subterranean shoots with tuberous swellings. These fresh tubers, after they have become disconnected, again form the starting-points for tuber-forming plants. This goes on until after a few years the soil all round the place where the first tuber had been is crowded with hundreds of separate tubers, and corresponding to these above the ground is a group of hundreds of separate leafy stalks. It depends of course on the number and length of the underground tuber-forming shoots whether the group is crowded or scattered. In the Artichoke

(*Helianthus tuberosus*) the tuber-forming shoots are short; the colony is therefore crowded, and only spreads slowly over a larger area. The Alpine Enchanter's Nightshade (*Circæa alpina*; see fig. 444 [3]) forms elongated tubers at the end of shoots 6 cm. in length, about 5 of them round the mother-plant, whilst each of the new plants arising from these tubers repeats this formation in the same colony. Since 6 cm. is a considerable length compared with the size of the Enchanter's Nightshade, the group is scattered and in a few years extends over a considerable area. The tuber formation of *Thladiantha dubia*, a gourd-like plant growing in

Fig. 444.—Plants with tubers and bulbs whose mode of growth leads to the formation of colonies arranged in lines and clusters. [1] *Muscari racemosum.* [2] *Thladiantha dubia.* [3] *Circæa alpina.*

Eastern Asia, is especially luxuriant; its shoot-formation is shown in fig. 444 [2]. In this plant a whole series of tubers which are chained together by thin threads 4–8 cm. long is formed on each shoot. Usually they form series of 5–10, and such a chain is about 50 cm. long. As a new plant grows from each tuber and again produces chains of underground tubers, the *Thladiantha* in a few years may occupy an area of 10 sq. metres, and will form a cluster which is both crowded and rapidly increasing in circumference. A further excellent example of the same thing is *Glaux maritima* which often spreads in the most diagrammatic manner in bare sandy places near the sea-shore.

Many tuber-forming plants producing clustered colonies inhabit marshes, especially such as are liable to great alteration in the level of the water and are exposed in years of drought to the danger of temporarily drying up. Many Pond-

weeds (*Potamogeton*), e.g. *Potamogeton pectinatus*, form a large number of small tubercles on their shoots which creep horizontally through the mud; *Scirpus tuberosus*, like the Alpine Enchanter's Nightshade, forms underground shoots 10–15 cm. in length, each terminating in a tuber as large as a chestnut, and since the plants to which these tubers give rise themselves repeat this formation of offshoots, the diameter of the clustered colony increases about 20–30 cm. every year. The Arrow-head (*Sagittaria sagittifolia*) also develops peculiar tubers. In the autumn, offshoots whose scale-leaves terminate in a sharp point not unlike those of the Couch-grass spring from the knotty stems hidden in the mud. The leaf which envelops the swollen end of the offshoot has a stiff point and plays the part of an earth-borer or rather of a mud-borer, since it makes a path for the offshoot which may elongate as much as 25 cm. The swollen end of the offshoot, which is about the size of a hazel-nut, bears a small bud with greenish, closely-folded leaves, and this, together with its tuberous support, remains alive during the winter, while the plant to which the offshoots owed their origin perishes. In the following spring each of the small buds grows up into a new plant at the expense of the reserve-materials stored in the tuber, and now instead of the old dead plant we have a small group of young independent plants rising from the mud.

The colonies of offshoots arranged in lines and clusters, which are developed from underground rhizomes and shoots, elongate horizontally, and form buds laterally and at their growing point, and in the same proportion as they fork and divide in front they die off behind, so that the individual sprouts become separated. To this category belong several species of *Dentaria*, *Anemone*, Couch-grass (*Agropyrum*), Mint (*Mentha*), Yarrow (*Achillea*), Willow-herb (*Epilobium*), Butterbur (*Petasites*), and the Woodruff (*Asperula odorata*). The length of the underground shoots which form the buds in these plants is very varied, as will be clearly seen from the table we insert here.

	Centimetres.		Centimetres.		Centimetres.
Anemone ranunculoides		*Epimedium alpinum*		*Hierochloa borealis*	
Monarda fistulosa	5–10	*Silene alpestris*	15–20	*Urtica dioica*	35–45
Melissa officinalis		*Mentha viridis*		*Carex pilosa*	
Origanum vulgare		*Asperula odorata*		*Glaux maritima*	
Achillea Millefolium		*Mentha piperita*	20–25	*Arnica Chamissonis*	45–55
Equisetum arvense		*Rubia tinctorum*		*Daphne Philippi*	
Asperula taurina		*Senecio Fuchsii*		*Senecio fluviatilis*	55–60
Oxalis corniculata	10–15	*Mercurialis perennis*		*Tussilago Farfara*	60–75
Betonica grandiflora		*Mentha crispa*		*Solidago canadensis*	
Tanacetum Balsamita		*Agropyrum repens*	25–30	*Petasites niveus*	75–85
Aster salignus		*Ægopodium Podagraria*		*Mentha alpigena*	
Dentaria glandulosa		*Convolvulus arvensis*	30–35	*Nardosmia fragrans*	85–100
Carex arenaria	15–20	*Saponaria officinalis*		*Epilobium angustifolium*	
Juncus arcticus		*Potentilla bifurca*	35–45	*Petasites officinalis*	100–150

These numbers do not represent the lengths of single internodes, but those of the whole annual underground shoots which may consist of many internodes. For example, the year's underground shoot of the Umbellifer *Ægopodium Podagraria* has 8 internodes, of which the proximal one is the longest and the distal the shortest.

The rapidity of the extension and the dimension of the colonies which are produced from rhizomes and runners depends upon the length of the annual shoot, and upon whether or not the soil is favourable to the spreading of the offshoots, just as it does in the linear or clustered colonies arising from underground roots and tubers. In wood-clearings and on the banks of rivers many of these plants develop in a surprisingly short time, as, for example, *Calamagrostis Epigeios, Epilobium angustifolium,* the North American Golden Rod and Rudbeckias (*Solidago Canadensis* and *Rudbeckia laciniata*), and these also have the property of suppressing and destroying all other vegetation in places where they have taken possession. This fact is turned to practical account by farmers who use certain Grasses which form linear and clustered offshoots to bind together loose soil, especially river sand. But there are also plants in this category which are veritable plagues to the farmer, the establishment and propagation of which he opposes by every means in his power. Examples of these dreaded plants, which, when they establish themselves in the fields and garden-beds, hinder the development of other plants, are furnished by the Gout-weed (*Ægopodium Podagraria*), the Stinging Nettle (*Urtica dioica*), and the Fuller's Thistle (*Cirsium arvense*). Wherever these have settled on cultivated ground and penetrated the soil with their offshoots there is nothing for it but to dig up the whole ground and to carefully remove all the shoots. Unfortunately even this laborious task is not always rewarded with the desired result, for in spite of the utmost care it may happen that small fragments remain, and these form the nucleus of a new colony of weeds. In a short time a new group appears above the soil which has been cleared with so much care, and a fresh digging and still more careful clearing of the ground is necessary. These clustered colonies have a characteristic appearance when foliage-leaves spring from their underground stem-structures, the large blades being borne on almost equally long erect stalks, as is the case, for example, in the Butterbur (*Petasites officinalis*) and numerous tropical Aroids. Wide tracts are then to be seen covered exclusively with their large luxuriant foliage-leaves, all other vegetation being suppressed. The formation of offshoots and the production of clustered colonies also occurs to a remarkable extent in the common Reed (*Phragmites communis*). Once settled on suitable soil it will cover the widest areas in uninterrupted and unhindered march, suppressing and destroying all other plants. On the lower Danube there are many lowlands so thickly set with Reeds that in several hours' journey only a few small inconspicuous plants will be seen beside the Reed haulms. This Reed is also interesting from the fact that its offshoots can arise just as well under water as under the ground, and it may serve, in some respects, as the type of a group of plants which, by reason of their amphibious nature, play an important part in the transformation of submerged into dry land.

On the other hand, the variety of the protonemal threads, runners, shoots, and creeping stems which spread above-ground from the offshoots of these colonies is almost inexhaustible. And this is readily intelligible. The processes which are connected with their formation are much more varied in plant-members which grow

in the light and in open air than in those which develop under the water or the soil, or, perhaps we should rather say, that above the ground the greater fluctuations in light, moisture, and temperature bring about corresponding modifications in the vital processes. Moreover, the substratum presents every imaginable gradation from shifting quicksand to heavy clay, from steep rock-faces in one place to the bark of old tree-trunks in another, all these having by no means the same effect on the formation of offshoots. One of the most noteworthy processes occurring above the ground leading to the formation of clustered offshoots is that exhibited by Moss-protonemas. By protonema is meant a web of threads which spreads sometimes as a loose, open network, sometimes as a thick felt, over rock, clay, sand, earth, humus, bark, and decayed wood, the individual cells becoming the starting-points

Fig. 445.—A section through soil permeated by the protonemal threads of the Moss *Pottia intermedia*. (Magnified.)

of new Moss stems. This protonema may be compared to a web of Strawberry runners which has spread over the ground in a wood-clearing. Just as small plants spring up from the thread-like runners in this case, so Moss-plants are produced from the protonemal threads, and by the dying away of the latter become isolated. In many Mosses the end comes with the formation of this clustered arrangement, as, for example, in the tiny Mosses classed together as Pottiaceæ, of which one species, *Pottia intermedia*, is shown in fig. 445. This plant has the following remarkable history. During the period when most other plants are engaged in active nutrition and reproduction it remains with its rhizoids and part of the protonemal threads imbedded in the ground. Numerous scattered spores also remain resting in the ground until at length the time for aërial development arrives. Strangely enough, however, this is not until late in the autumn, when the leafy trees have discarded their foliage and autumnal mists drift through their bare branches. Then on the surface of the bare, cold, damp earth appear green threads which at first look like algal filaments, and on these small buds are formed (see fig. 445). In the course of a few weeks Moss-plants grow up from these buds

which become independent by the gradual withering and decomposition of the connecting pieces of thread. They form spherical spore-capsules, and with the scattering of the spores they wither and die. These plants are only a few millimetres high, but they are clustered together in such thousands that they form a velvety carpet over the soil, their emerald-green colour being the more striking as the last remains of the neighbouring vegetation have assumed the dull hues of decay. The Luminous Moss (*Schistostega osmundacea*) growing in the holes and clefts of slate mountains (already described in vol. i.), the protonema of which is depicted in Plate I., also forms loose colonies of separate Moss-plants from the green threads which creep over the clayey soil in the hollows. These plants die off after they have ripened their fruits. Of course the development is in this case not so rapid and does not occur in the late autumn as in *Pottia intermedia*.

A peculiar formation of offshoots may be noticed in epiphytes which climb over the bark of old trees and possess only short ribbon-like roots adhering to the damp bark, but none which grow down into the ground. Their stems and leaves invest the substratum like a carpet, as, for example, in several tropical Aroids of the genus *Pothos*, and in *Marcgravia*. The growing stem forks, and later on by the dying away of older portions behind the fork the two branches are separated and isolated. Each in its further growth may go a different way, one climbing up this and the other up that branch of the tree-trunk which serves as support; and, since this process is repeated, several independent plants of *Marcgravia* and *Pothos* may be found on the crown of the tree, all of which are to be regarded as natural offshoots. The same thing occurs in numerous Ferns, which grow on the bark of trees and in the humus-filled clefts of rocks, and in all those plants whose creeping aërial stems grow and branch at one end while they die off to a corresponding extent behind, as in many creeping species of clover, for example. As the annual increase in the stem of these plants is but small, the separated individuals move very slowly from one another, and several years elapse before the offshoots have formed a group which extends over an area of a square half-metre.

The result is obtained comparatively much quicker when the offshoots are formed by runners and shoots. In one section of these plants, of which the *Saxifraga flagellaris* (fig. 446), a plant widely spread through the Arctic region and in the high mountain districts of the Himalayas, Altai, and Caucasus, may be taken as a type, only a single bud is developed at the end of a slender thread-like shoot. This takes root where it touches the ground, and grows up into a rosette. Not until the nourishment of the rosette by the rootlets which have been sent into the ground is assured does the long thread, terminated by the bud, die off, the connection with the mother-plant being thus severed, whilst the rosette now forms an independent plant. Since the shoots are usually numerous and radiate outwards the mother-plant in course of time becomes surrounded with an actual garland of rosette-shaped offshoots, and in a few years a fairly large area is covered with hundreds of larger and smaller rosettes, which, however, no longer show the circular arrangement, because the shoots of neighbouring rosettes often cross, and consequently the circles intersect.

Everyone knows the long runners of the Strawberry plant (*Fragaria vesca*). Here buds arise at the intermediate nodes as well as at the tip of the runner, and these develop into new plants after the thread-like connecting portions have perished. Suppose a Strawberry stock sends out three runners during the summer; each takes root at 5 nodes, and from each node a bud, *i.e.* an offshoot, develops, so that the following year the mother-stock is surrounded by fifteen daughter-plants. It should be noted that the length of the internodes in each runner is unequal. For example,

Fig. 446.—Formation of a clustered colony by means of aerial runners in *Saxifraga flagellaris*.

in one which had extended over the ground in the shade of the wood, the first internode was 37, the second 34, the third 31, the fourth 30, and the fifth and last 22 cm.; thus the offshoots were the closer together the greater their distance from the mother-plant. Next summer fifteen new offshoots were again formed from each of the original fifteen, arranged in exactly the same way, and in the forest-glade, where two years previously there had been only a single Strawberry plant occupying a space of 50 sq. cm., there would now be 200 plants distributed over a space of about 3600 sq. cm.

The lesser Spearwort (*Ranunculus reptans*), the Ground Ivy (*Glechoma hederacea*), and the creeping Cinquefoil (*Potentilla reptans*) display quite as

considerable an increase and distribution as Strawberries. The accompanying table gives the length of runners and shoots of some well-known species in which the formation and rapid distribution of offshoots is particularly noticeable on suitable substrata.

	Centimetres.		Centimetres.		Centimetres.
Saxifraga Aizoon	4	*Lycopodium annotinum*	30–40	*Vinca herbacea*	70
„ *cuneifolia*	6	*Saxifraga sarmentosa*	40	*Fragaria Indica*	85
„ *Geum*	8	*Ranunculus Flammula*		*Potentilla anserina*	110
„ *flagellaris*	10	*Geum reptans*	} 50	*Glechoma hederacea*	126
Sempervivum stenopetalum	12	*Glyceria fluitans*		*Potentilla reptans*	130
Viola odorata	13	*Lithospermum purpureo-*		*Rubus saxatilis*	140
Arabis procurrens	16	*cœruleum*	56	*Fragaria vesca*	150
Androsace sarmentosa	18	*Ranunculus reptans*	60	*Vinca major*	200
Ajuga reptans	20	*Tiarella cordifolia*	65	*Rubus Radula*	300
Hieracium flagellare	30	*Vinca Libanotica*	66	„ *bifrons*	650

In those cases in which plants change their position by the development of offshoots in any direction, whilst they die off in the opposite one, progress is always restricted. The offshoots penetrate only by slow degrees in the surrounding soil, and many years elapse before a space of 100 metres is traversed in this way. The change of position is much more rapid when the offshoots become detached from their place of origin and are carried to a new spot by special mechanisms of transit, by currents of water, the wind, or finally by the help of men or animals. In this way it may happen that single detached cells, cell-groups, buds, and shoots may be carried vastly further than 100 metres in a few minutes, through long valleys, over steep precipices, or even over high mountain ridges. This rapid distribution is not indeed so certain in its result as the slower mode of progression. It may easily happen that the wind or water current lands the detached offshoot on some spot where further development is impossible, where it must inevitably perish. Apparently, however, this disadvantage is compensated for by the immense quantity of such detached offshoots. Again, there are plants which form two kinds of offshoots, those which propagate slowly but surely, which are few in number, and others, developed in large numbers, which are distributed rapidly but less certainly.

Only a very small proportion of plants develop offshoots which after they become detached reach a new locality spontaneously, by means of special organs of motility. This class of brood-body is always aquatic and of very small size, and its development can only be followed under the microscope. The best-known examples are Fungi, belonging to the Saprolegniaceæ and Chytridiaceæ, the dark green Vaucherias, and other species of Algæ. The Saprolegnias are saprophytes growing in and on the bodies of animals which have died in the water—not only fish, crustaceans, and insect larvæ, but also birds. They form delicate, thread-like, tubular hyphæ, which ramify repeatedly, and part of which penetrate into the corpse like a root-plexus, while the rest rise up above the body in the form of white or grey felt, which floats in the water. Single tubular erect hyphæ assume a knob or club-shaped form, and their protoplasm divides up into numerous portions. Ultimately the club-shaped tube opens at the apex, and the little proto-

plasmic bodies (swarmspores) escape (*cf.* fig. 192, p. 17). What happens next differs according to the species. In the genus *Saprolegnia* the individual swarmspores have two cilia, by means of which they immediately swim away (see figs. 192[6] and 192[7]); in *Achlya*, on the other hand, the swarmspores group themselves into a round ball in front of the opening of the tube as they escape (*cf.* fig. 192[1, 2, 3, 4]), and at first possess no cilia. They surround themselves there with a delicate capsule, which apparently consists of cellulose, but they do not remain long in this condition. A few hours after, they leave the capsule and assume a bean-shaped form, being now provided with cilia which enable them to swim about in the water. They only swim about for a comparatively short time. When they have settled on some spot they lose their cilia, surround themselves with a cell-wall, and become the starting-point of a new plant; therefore they must certainly be regarded as offshoots. The Chytridiaceæ have a similar offshoot formation. These too are devoid of chlorophyll, but they are true parasites, not saprophytes like the Saprolegniaceæ. They prefer green water-plants for their hosts, penetrating into their cells, killing and destroying the protoplasm, and then develop thick tubes which project beyond the host-plant, and in which the protoplasm becomes divided up into numerous spherical portions. The tubes open at their apex sometimes by the raising of an actual lid (see fig. 192[5]), sometimes by the dissolution of a limited portion of the cell-wall, so that a hole results from which the isolated protoplasts are expelled. On its escape each of these offshoots is spherical or egg-shaped in form, and possesses a single long cilium. This cilium serves as a swimming organ which in many species actually causes a hopping and springing movement. In order to avoid repetition, we may refer to the description of the swarmspore-formation given at vol. i. p. 29, in the case of the Vaucherias and Sphærellas.

On the whole, as we have already stated, the formation of offshoots which swim about independently in the water and seek out new spots suitable for settlement is restricted to a very small section of water-plants. Offshoots which, after their detachment from their place of origin, are carried passively by water currents without exercising any directive influence, and are stranded at some distant spot, are of much more frequent occurrence. Of these water-plants we might mention in the first place the filamentous green Algæ which cover with slimy masses the surface of slowly moving water or stones at the bottom of rapid streams. In many of these plants several times during the year do the dividing membranes between the individual cells break down into mucilage so that the cells become free and are carried away by the flowing water. Each of these cells may again give rise to a new thread by repeated division. We cannot easily conceive a more simple method of propagation and distribution than this. The offshoot-formation in the Florideæ is hardly less simple. Whether the whole plant is composed of rows or of open networks of cells, four protoplasmic balls, the so-called tetraspores, are formed in various situations on the plant; these are liberated into the surrounding water and carried away by the current. They adhere to some firm spot under water and there grow up into new plants. In most instances the protoplasm of the cell in

which the offshoot formation occurs is divided into four, more rarely two or eight clumps are formed by the splitting and dividing of the protoplasm, and most rarely of all is the whole undivided protoplasm of a cell transformed into a single offshoot.

The small group of water-plants known as the Hydrodictyaceæ display a peculiar offshoot-formation. In the elegant Water-net (*Hydrodictyon utriculatum, cf.* p. 640), whose cylindrical cells form a closed net with hexagonal meshes, the cells each originate new plants as Water-nets in miniature. The protoplasm in one of

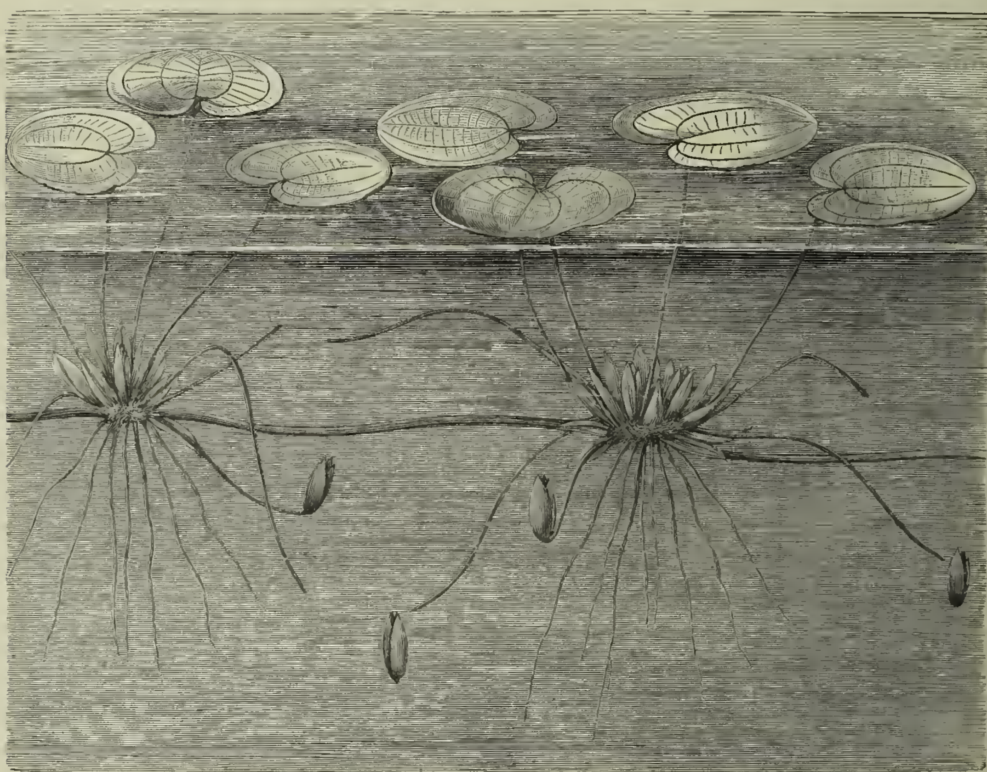


Fig. 447.—Frogbit (*Hydrocharis Morsus-ranæ*). The winter buds in process of detachment from the ends of the submerged stolons.

the cells which is preparing for offshoot-formation divides into many thousand parts which quiver in a remarkable way and pass between one another, and are said to undergo the so-called swarming motion. This lasts about half an hour, then the swarming portions, whose rod-like form can be recognized in spite of their minuteness, come to rest, arrange themselves into nets with hexagonal meshes (see figs. 370 [3, 4, 5,] p. 640), and now each cell contains a tiny Water-net. The outer layer of the cell-wall in which this grouping has taken place is partially dissolved. The little net, at first still inclosed in a pellicle of protoplasm, slips out and swims freely in the water as an offshoot. In 3–4 weeks it has attained the size of the Water-net, from one of whose cells it emerged, and in each of its own cylindrical cells the same process may be repeated. A similar process is observed in the small water-plant

called *Pediastrum*, which is closely related to the Water-net, and of which one species is shown in figs. 370 [6, 7, 8], p. 640.

The distribution of bud or sprout-like offshoots is seen especially in the Duckweeds, Alismaceæ, Potamogetons, Utriculariaceæ, Droseraceæ, and Primulaceæ. Most of the Duckweeds (e.g. *Lemna polyrrhiza* and *L. arrhiza*), which float during the summer on the surface of still water, towards the autumn form organs on their flattened stems which become detached from the summer plants, sink to the bottom

Fig. 448.—Frogbit (*Hydrocharis Morsus-ranæ*). [1] Winter buds rising to the surface in spring. [2] Young floating plants which have developed from such buds. [3] Older floating plants.

of the lake, and stay there during the winter. Each of these organs is pocket-shaped, and in the hollow the next year's shoot is already laid down—of course, as a minute structure whose semicircular free end scarcely projects above the closely-adjoining edges of the pocket. These detached winter buds sink because their cells, even those of the epidermis, develop large starch grains which are crowded together, and literally fill up the lumens of the cells. There are no air-spaces like those which cause the summer-plants to float on the surface of the water; the stomata as yet are closed, and the whole body, hermetically sealed from the outer world, now has a specific gravity which causes it to sink down to the bottom of the water, where it is protected against the frost. There it remains in a resting condition during the winter. At the beginning of the warmer season the bud wakes from its winter

sleep, the starch-grains are used up in the building of the young stem, and the growing buds of these species of *Lemna* again rise to the surface of the water, because the cells which had served as storehouses for the starch become empty, and because air-spaces are formed in the new tissues.

The same change of position during the year is also observed in the offshoots of the Frogbit (*Hydrocharis Morsus-ranæ*), which is common in still waters through the whole of Europe and a great part of Asia. Although this plant is abundantly provided with roots, it never fixes itself by them to the slimy bottom of the pool in which it lives. Throughout the summer it remains floating on the surface, spreading its foliage like the Water-lilies on the top, while its roots hang below in the upper layers of water. Its propagation in the summer is very rapid by the formation of offshoots. These arise in the axils of foliage-leaves from the very short, erect, floating stem, and are rather long, resembling thick threads, which keep close to the surface of the water, and grow in a horizontal direction. Each shoot terminates in a bud, and this quickly opens, sending up green foliage to float on the water, and a bunch of roots below. In a very short time the plant thus formed resembles the parent which gave it origin, and is itself able to develop new shoots. Thus it comes about that in a few weeks the surface of the water is covered with innumerable floating plants of Frogbit, every 10–20 being connected together by horizontal strands. The pretty flowers now rise above the surface from the stronger plants. The flowering is, however, of short duration, and is seldom successful, *i.e.* fruits with fertile seeds are rarely produced. As soon as the blossoming is over and autumn approaches, new shoots ending in buds appear. They are shorter than those of the spring, and they sink lower on account of the greater weight of the buds they carry. The buds, too, have a rather different form. They are firm, and wrapped in closely-fitting scale-leaves, and they almost attain the size of a small date-seed. As soon as the bud is provided with the requisite amount of starch and other reserve food-substances, it becomes detached from its filamentous support, and sinks down (see fig. 447) till it rests on the mud at the bottom of the pond. The plants floating above, which gave rise to them, die off completely and decay. It is high time indeed to quit the field above, for the surface of the water is soon covered with a sheet of ice, which renders all vital activity impossible for months. When spring again arrives, and the ice vanishes from the pools and ponds, new life rises up from the mud below. The buds of the Frogbit which have passed the winter there become spongy, the cell-cavities fill with air, and the whole structure rises to the surface (see fig. 448 [1]). Arrived there the scale-leaves rapidly separate, green leaves expand their blades on the sunlit surface, roots hang down into the water, and before long, shoots are again developed as already described (fig. 448 [2]). Obviously deviations of position and sometimes considerable changes of place are brought about by the sinking and rising of the buds in the water. It is observed, too, that the Frogbit is very variable in regard to its position, and that sometimes a place whose surface was one year covered with numberless plants will in the year following present no trace of them, while new colonies will have developed at a distance.

The Bladderworts (*Utricularia*), Aldrovandias (*Aldrovandia vesiculosa*, see vol. i. p. 151), and the Water Violet (*Hottonia palustris*), which desert the cold upper strata of water as winter sets in, and sink down to the relatively warm depths below, develop special wandering buds for this purpose; these are not enveloped in scale-leaves like those of the Frogbit; they are in reality merely much abbreviated shoots whose leaves are so crowded and folded so closely together, that the whole shoot looks like a rounded green ball. These balls at first remain connected to the piece of the floating stem which gave them origin. This attachment is lost towards the end of autumn, and the little buds sink down to the bottom of the pond and necessarily get distributed in various directions. Next summer, when the balls leave their winter quarters and are again carried to the upper strata of water, they expand into foliage-bearing plants. It has been already stated (vol. i. pp. 76 and 658) that the Water Soldier (*Stratiotes aloides*), which is closely-related to the Frogbit, undergoes similar changes during the year, and we need here only draw attention to the fact that it sinks down to its winter quarters at the bottom of the pond as an open rosette, and not in the form of buds, and rises again the ensuing spring when the weather is more favourable.

The Pondweeds *Potamogeton crispus, obtusifolius, pusillus,* and *trichoides* behave differently from the marsh and water plants hitherto described. Here, as autumn approaches, buds are developed which become detached from the old decaying stems (fig. 136, vol i. p. 551), and sink down to the bottom of the pond; but in the following summer they remain sticking in the mud at the spot where they fell, and do not rise again to the surface. They send out roots and develop much-branched leafy stalks, and these rapidly grow up to the surface of the water. These Pondweeds, firmly rooted to the bottom of the pond, multiply not only by these free-swimming offshoots, but also by stolons which creep far and wide through the mud; but of course the plants are distributed to much greater distances by the sprouts or buds which are developed in the autumn on the upper internodes, and which then become detached and float in the water, than would be possible by the creeping stolons alone.

A very remarkable distribution of offshoots is to be observed in the marine *Cymodocea Antarctica*, which is very common on the coast of Australia, south of the Tropics. This plant has an erect stem, thickly covered with dull-green foliage-leaves, arranged in two rows. The lower leaves fall off prematurely, and the bare scarred stem then carries only a bunch of ribbon-shaped leaves at its summit. Towards the close of the winter the end of the stem above these leaves is seen to become peculiarly modified. Its internodes become much contracted, and at the lowest node is developed a scale-leaf with four lobes, which surrounds the leaves developed from the upper nodes, like a cup. Buds arise in the axils of one or two of these leaves, while the leaves themselves die and decay. The parenchyma of the four-lobed, cup-shaped scale-leaf also decays, and only its stiff veins remain, so that instead of the cup, there are now only comb-like scales. After this alteration has taken place, the tissue of the stem below the pectinate scales breaks across,

and the whole shoot-apex, separated from the lower part of the stem, which has long been in a leafless condition, is carried away by the currents of the water. How far and for how long the shoot is carried about depends upon the local condition of the sea-shore. Sooner or later its career of wanderer is arrested by the trailing comb-like scales assuming the rôle of anchors. As soon as the anchor is fast, some 2–4 roots develop from the lower internodes of the shoot; these pass between the teeth of the comb-like anchor, and grow down into the muddy substratum, thus fixing the offshoot. All this happens at the end of winter. During the following summer, the shoot, which is about 8 cm. long, and is anchored and rooted in the mud, again grows up into a stem about a metre high, and next winter its top again falls off just in the same way. It has already been mentioned (p. 457) that this strange sea-plant very rarely blossoms or fructifies—a circumstance which confirms the supposition that the boundless colonies of it round the coasts of Tasmania owe their origin to the offshoots distributed by the sea currents.

The distribution of offshots by sea-water is a much simpler affair in the Sea-wracks, Ulvas, and Florideæ than in these other water-plants. When the sea is stirred to its depths by violent storms and the spring-tide is higher than usual the retreating waves leave any quantity of fragments of these plants behind them. These have been torn by the raging water from the firmly-fastened ribbons, nets, and threads below, and are then carried away by the billows. The water drives them into clefts of the rocky coast or imbeds them in the sand and mud of the shore, and, wonderful to relate, not a few of them flourish again, granted of course that they are not speedily removed by subsequent tides and that the circumstances are otherwise favourable.

Much the same kind of thing happens on the banks of rivers and streams. A portion of the plant-fragments brought by floods and stranded on the mud of calm inlets undergoes decomposition. A larger portion remains fresh and living, sending out roots and vigorous shoots. In the bed of the Danube, in addition to the abundant creeping shoots of the Reeds (*Phragmites*) and various Sedges, Bulrushes (*Scirpus, Typha*), broken twigs of *Salix fragilis*, bits of roots of the Sea Buckthorn (*Hippophae rhamnoides*), fragments of the rhizomes of *Œnanthe Phellandrium* and *Acorus Calamus*, leafy twigs and stolons of various species of Pondweed, Water-Milfoil, and Water Ranunculus (*Potamogeton, Myriophyllum, Ranunculus aquatilis*) are all distributed in this way. Sometimes these growths settle in places where formerly no specimen of the kind had been seen for miles, and the fact may be easily confirmed that the distribution of their offshoots is actually brought about by flowing water in a very short time to great distances and in great abundance.

The distribution of offshoots in little brooks which flow down between Reeds and Rushes with a moderate fall, and scarcely ever overflow their banks takes place more quietly. A rapid flow occurs only in the middle of the channel, but near the bank, and especially in the small inlets, the water is almost as still and calm as in a closed-in lake. Here in these quiet spots are also to be found floating

plants brought by birds; their roots are either not fixed to the ground but sway about in the water, or they may be altogether absent; examples are, *Riccia fluitans* and *R. natans*, *Lemna* and *Wolffia*, and in tropical regions *Azolla* and *Pistia*. All these multiply very rapidly. While they continually branch at one end, forming spreading lobes and sprouts, they die away on the other, the result being of course a separation into several pieces, *i.e.* into offshoots. These fragments spread themselves like a green mosaic over the surface of the water. As the offshoots increase in numbers a certain number of them will extend beyond the calm inlet by the bank into the flowing water in mid-stream. Here they are hurried away by the current, and it often happens that they travel some distance before they are again stranded in some calm spot near the bank to form again the starting-point of a fresh aggregate of offshoots.

Rain-water also plays an important part in the distribution of offshoots. Those of the widely spread Liverwort, *Marchantia polymorpha*, so frequently met with on damp earth, are especially noticeable in this respect. Their development is represented in fig. 196, p. 23. On the surface of the dark-green leaf-like thallus of this Liverwort cups arise, at the base of which papillae give origin to plate-like brood-bodies (gemmæ, *cf.* figs. 196 [2] and 196 [3]). Other papillæ behave differently, and undergo only slight enlargement. The heads of these latter then swell up forming a gelatinous mass, and as this swells up it raises the green gemmæ higher and higher out of the bottom of the cup (fig. 196[2]). At last they get close to the edge and are washed out of it by the rain. The offshoots of other Liverworts are also chiefly distributed by rain-water, as for instance the gemmæ which arise in the crescent-shaped pockets of *Lunularia*, and in the flask-shaped cavities of *Blasia pusilla*. The pairs of cells which arise on the upper surface of *Aneura multifida*, the single cells which become detached from the edge of the fronds of so many Liverworts, the multicellular offshoots which are given off by *Radula complanata* so common on the bark of trees, the round cell-plates growing on the edge of the leaf-like thallus of *Metzgeria pubescens*, and finally the ball- and disc-shaped groups of cells which develop on the surface of the leaves of numerous Mosses (*e.g.* on various species of the genera *Leucobryum*, *Grimmia*, *Zygodon*, *Orthotrichum*, *Barbula*, *Calymperes*). In many of these cases the small offshoots are detached as well as distributed by the action of rain-water, but in others the loosening occurs before the rain begins, and in *Blasia* and *Aneura*, as well as in *Marchantia*, the offshoots are first separated by mucilaginous membranes, and are thus raised up from their attachment. Not until afterwards are they washed out and distributed by the falling rain. These small offshoots can of course also be carried away from their place of origin by strong gusts of wind. Even breathing strongly on them is sufficient to detach the uppermost gemmæ of *Marchantia*, but in dry air and in dry soil they rapidly shrivel up and perish. The distribution by currents of air is therefore not attended by success, but the offshoots of the Liverworts and Mosses washed out by showers of rain immediately begin to grow, and quickly attain to further development. This mode of distribution plays an

important part in the covering of tree-trunks with Mosses and Liverworts. A small patch of *Radula, Metzgeria* or similar plant having once taken hold, when a downpour of rain beats upon the trunk quantities of tiny ball- and disc-like offshoots float away to be caught again by projecting irregularities of the surface; indeed the rapid covering of old trunks with green carpets and mantles of Liverworts and Mosses is for the most part effected by rain-water.

It is comparatively seldom that bud- and sprout-shaped offshoots are distributed by rain. But there is one very interesting example of this, viz. the widely-spread Lesser Celandine (*Ranunculus Ficaria*), a single plant of which is shown in fig. 343 [3], p. 460. In the axils of the foliage-leaves of this plant are developed offshoots which have the form of small tubers, and which are not unlike the youngest stages of small potato-tubers (fig. 343 [6]). When the leaves and stalk of the Lesser Celandine begin to turn yellow and wither in the early summer, the tubers break away from the stem and fall to the ground. There they usually escape observation, since they are hidden by the yellowing foliage; but should there come a heavy storm of rain the withered leaves are pressed down on to the soil by the force of the rain-drops, and the scattered tubers become visible. Sometimes the impact of the falling rain-drops hastens the detachment of the tubers from the mother-plant. When the rain is so heavy that the water flows away in the form of small rivulets, the loose tubers are washed off in abundance. A sudden downpour of rain in a region abundantly overgrown with Lesser Celandine is sufficient to float away numbers of the tubers, and heap them up on the borders of irrigation channels when the rain disperses. In such places the quantity of tubers which have floated together is often so large that one can hardly gather them in one's hands. In this way arose the idea that the tubers had fallen from heaven with the rain, and the myth of a rain of potatoes.

The small tubers which arise in the axils of the leaves of *Gagea bulbifera* (*cf.* fig. 343 [1], p. 460), a plant growing on the steppes of Southern Russia, are distributed by rain-water just like those of the Lesser Celandine. This brings us to the question of the much-discussed manna-rain in steppes and deserts, which in reality is nothing but the distribution of the offshoots of a Lichen, viz. the Manna-lichen. This Lichen, which was termed *Lichen esculentus* by the older Botanists, but in recent times has been referred to the genera *Urceolaria, Lecanora, Chlorangium,* and *Sphærothallia,* and which apparently consists of three species, viz. *Lecanora esculenta, L. desertorum,* and *L. Jussufii,* is spread over an enormous region in south-west Asia, and extends as far as the south-east of Europe and the north of Africa. This Lichen is met with in the neighbourhood of Constantinople, in the Crimea and Caucasus, in Persia (whence the illustration at page 695), also in Kurdistan, Arabia, and the Anatolian high land from Bulgar Dagh in the Taurus (where it is very often met with at a height of 2700 metres above the sea), and finally in the Sahara and the deserts of Algeria. It first forms thick wrinkled and warted crusts on the stones, preferably on small fragments of limestone lying about; the outer colour of the crust is a grayish yellow, while on breaking it appears as

white as a crushed grain of corn. As they get older the crusts become rent, and separate either partially or wholly from their substratum. When they first become loosened the edges of the detached portion become somewhat rolled back. The rolling then continues, and ultimately the loosened piece forms an elliptical or spherical warted body with a very much contracted central cavity. Small stones are sometimes imprisoned in this way within the cavity of the sphere, in which case the weight of the loose Lichen is correspondingly increased, but as a rule the hole is filled with air, and when dried the pieces weigh very little. Ten loose pieces of Manna-lichen, each as large as a hazel-nut, weighed 3·36 grams, and the weight of a single piece therefore was on an average only ·34 grams. It is easy to see that the loose portions will be rolled about by the wind, and that a storm will sometimes sweep them up from the ground and carry them hither and thither through the air. This method of distribution appears to be the prevailing one in regions where the supply of water is not abundant in the rainy season, and where violent storms rage from time to time. That this is so is confirmed by the circumstance that the Manna-lichen after the storms lies chiefly piled up behind the low bushes and undergrowth, *i.e.* just where the force of the storm has been to some extent broken, and where the shifting sand has been heaped up into little hillocks. Where a period of heavy rains succeeds the long dry summer, however, and where such a quantity of water falls on the parched land that it cannot all be absorbed, some of the rain collects into small rivulets. These carry away with them everything which is movable and capable of floating. The turbid rivulets flow down over the inclined soil to the lowest parts of the country and there unite into larger streams, or if it can find no outlet the water remains for some time in the hollows as small pools and puddles, and deposits there the mud and vegetable débris it has carried with it. The latter is more especially the case on the steppe soil overstrewn with small stones where between the slight elevations there is a labyrinth of shallow channels and winding depressions resembling ploughed land. In such regions the Manna-lichen is chiefly washed into the depressions by the rain-water, and in some years in such quantity that they form heaps a span high, and a single man can in a day collect 4–6 kilograms (about 12,000–20,000 pieces, varying in size from a pea to a hazel-nut). This is especially the case in the steppe region and in the high lands of South-west Asia, where the Manna-lichen is used as a substitute for corn in years of famine—being ground in the same way and baked into a species of bread. That the rain-water is the agent which transports the Lichen in these regions is beyond doubt, because the pieces heaped up in the hollows are not in the least rubbed on their outer surfaces as would certainly be the case if they had been rolled and dragged even for only a short distance over stony ground. It is also remarkable that all the great so-called rains of manna, of which news has come from the East to Europe, especially those of the years 1824, 1828, 1841, 1846, 1863, and 1864, occurred at the beginning of the year between January and March, *i.e.* at the time of the heaviest rains. When we remember that the inhabitants of the district actually thought that the manna had fallen from heaven, and quite overlooked the

fact that this vegetable structure grew and developed (although only in isolated patches and principally as crusts on stones) in the immediate neighbourhood of the spots where they collected it, we need not be surprised at the conclusion of our own peasants who thought the tubers of the Lesser Celandine had fallen with the rain from heaven. It should be mentioned that the manna sent to the Israelites on their journey out of Egypt to the Holy Land is identical with the Lichen described here and figured on page 695, and the older view that the manna of the desert was the sap of a Tamarisk (*Tamarix gallica mannifera*) exuded under the influence of a parasite is without any foundation.

Spores take the first place among the reproductive bodies which are distributed by wind. Many Ascomycetes develop some of their spores by abstriction from the free ends of special hyphæ. These rise up into the air from the substratum, which is permeated or covered by the mycelium. In this way the separated but loosely-adhering spores can be carried away by the slightest atmospheric movement. In the Moulds known as *Aspergillus* and *Penicillium*, whole series of spores are cut off from the end of each hypha (see figs. 193 [4, 5, 8, 9], p. 18), and as they are crowded closely together a single breeze carries off innumerable quantities of spores. By breathing only lightly on the small forest-like colonies of supports the spores are whirled as dust into the air, and as they are extremely light they not only remain a long time suspended in it, but even in perfectly still air are carried sometimes up, sometimes down, by the currents due to slight differences of temperature, again being carried horizontally or whirled along until at last they settle, and become the starting-point of a new Mould formation. The spores abstricted from the ends of the so-called sterigmata in the Hymenomycetes (see figs. 389 and 390 [7]) may also be detached and carried away by wind, but apparently most of the spores in these Fungi separate spontaneously in calm air and fall to the ground, covering it with a delicate layer of dust, to be afterwards carried away from this resting-place by breezes.

The spores of Ustilagineæ and those in the æcidia of Uredineæ (see p. 686) are at first covered with delicate membranes and sometimes inclosed in special receptacles. As soon as they are mature they form a powdery mass, which bursts through the covering membrane, and the now exposed spores are blown away as dust by the wind. If they have developed in deep receptacles shaking is necessary before they can be blown away. The spores then fall from the mouth of the receptacle into the currents of air. In many Myxomycetes and Gasteromycetes (see fig. 367 [2], p. 618, and fig. 391 [3], p. 690) delicate twisted threads called the capillitium are developed simultaneously with the spores. The web of threads with the spores between them is inclosed in a membrane (see fig. 449 [1]). When this membrane bursts at maturity and the receptacle is thrown open only the spores in the immediate neighbourhood of the opening can be blown away by the wind, the deeper ones being held back by the capillitium. The lower layers of the capillitium are then raised by the action of dry winds, and thus quantities of new spores are continually carried from below up to the opening. In this way it happens that the spores of these plants are only

distributed in small detachments, and only at a suitable time, *i.e.* when a dry wind is blowing. A similar contrivance is exhibited by the Muscineæ in the Marchantiaceæ, Anthocerotaceæ, and Jungermanniaceæ. Peculiar filamentous, very hygroscopic cells with spiral bands of thickening on the cell-wall, are found with the spores in the receptacles of these plants (see p. 696). These have been called elaters, because it was thought that their movements caused the ejection of the spores. Their significance, however, rather lies in the fact that they serve to hold the spores together after the opening of the receptacle, and only expose them by degrees to the wind. They also help to burst open the receptacles, but that hardly concerns us just now.

Fig. 449.—*Trichia clavata.*

1 The membrane of the sporangium has burst, and the capillitium has bulged out raising up the spores embedded between its threads and exposing them to the wind; ×20. 2 Threads of the capillitium with the spores lying between them; ×250.

Only three of the most striking of the varied contrivances for spore distribution by wind in Mosses (which are destitute of elaters) will be here described. First, those which are observed in the Andreæaceæ (see figs. 450 [1] and 450 [2]). Here the capsule opens by four longitudinal clefts which, however, do not extend quite to the free end, and the four pieces into which the wall is thus divided may be compared to the staves of a barrel joined together at the top. In damp weather they become approximated, so that the clefts are closed (fig. 450 [1]). In dry weather the valves become arched, the clefts widen, and the spores may be blown out from the interior of the capsule by the dry wind (fig. 450 [2]). The distribution of the spores is effected quite differently in the Polytrichums, one species of which is illustrated in figs. 450 [3, 4, 5, 6, 7, 8]. After the roof (operculum) which formerly surmounted the capsule has fallen off a delicate whitish membrane comes into view, which is held fast by the points of numerous sharp teeth, and is stretched like the skin of a drum over the mouth of the capsule with its annulus. If rain and dew moisten the Moss the teeth are seen to be much bent inwards, the membrane lying upon the annulus, and completely closing the receptacle (fig. 450 [5] and 450 [7]). But in dry air, especially when a dry wind is blowing, the teeth turn rather outwards, raising the membrane above the annulus, and thus small holes are left between the teeth through which the spores can escape (figs. 450 [6] and 450 [8]). The same dry wind which causes the alteration in the position of the teeth now shakes the spores out of the capsule, which is borne on an elastic seta. *Grimmia ovata,* one of the Bryaceæ (see figs. 450 [9] and 450 [10]), may be taken as the type of a third contrivance for exposing the matured spores to the wind in dry weather, retaining them in the receptacle when it is damp and protecting them there from the injurious effects of moisture. The circular mouth of the pipe-bowl-shaped receptacle is furnished with

teeth, each of which terminates in a free point. The tissue of these teeth is hygroscopic, and their direction and position alter to a surprising extent according to the degree of humidity of the air. In damp weather the teeth are so close together that they completely shut the capsule (fig. 450 [9]), but in dry weather they bend outwards (fig. 450 [10]), and the spores are shaken out of the capsule and scattered by the wind.

We shall have to describe presently how the sporangia of most Ferns dehisce

Fig. 450.—Dispersal of spores by wind.

[1] Spore-capsule of an *Andreæa* in damp weather. [2] The same in dry weather. [3] Spore-capsule of a *Polytrichum* in damp weather. [4] In dry weather. [5] The spore-capsule of a *Polytrichum*, the edge of the mouth beset with teeth and covered with a membrane, in damp weather. [6] In dry weather. [7] A part of the peristome more highly magnified, in damp weather. [8] In dry weather. [9] Spore-capsule of a *Grimmia* in damp weather. [10] In dry weather. [11] Racemose sporangia of a *Botrychium* in damp weather. [12] In dry weather. [13] A single sporangium of this *Botrychium* enlarged, side and front view, in damp weather. [14] In dry weather. [3], [4], [11] and [12] nat. size; the others enlarged.

suddenly so as to scatter the spores. In such Ferns the sporangia are developed on the under side of the frond, and this position protects them excellently against any injury which might befall them from rain or dew. But there are some Ferns whose sporangia are exposed to both rain and dew, and whose spores are not suddenly scattered by the bursting of the sporangia. Among others, the Moonwort (*Botrychium*) may be mentioned. Its branched spike of sporangia is represented in figs 450 [11] and 450 [12]. The elliptical sporangia of the Moonwort open by a transverse slit, but the two valves thus formed only separate in dry weather (figs. 450 [12]

and 450 [14]) when the spores may be shaken out and blown away. As soon as the sporangia are moistened the two valves immediately shut together (figs. 450 [11] and 450 [13]) and obviously the spores can no longer be shaken out. A similar opening and shutting of sporangia according to dryness or moisture may also be observed in the Lycopodiaceae (see fig. 405 [4], p. 716).

A similar phenomenon may also be observed in the sporangia of the Horse-tails (see fig. 403 [4], p. 712). Here not only the sporangia but the spores themselves present a very different appearance according as they are dry or damp. The wall of these spores consists of several layers, of which the outermost splits up spirally to form two arms which remain joined to the spore at one spot. In dry weather the two spiral bands, which are arranged in the form of a cross, unroll (see fig. 451 [1]) and constitute four appendages which afford enough purchase to the wind to enable the comparatively large and heavy spores to be carried away. If the spores fall on to

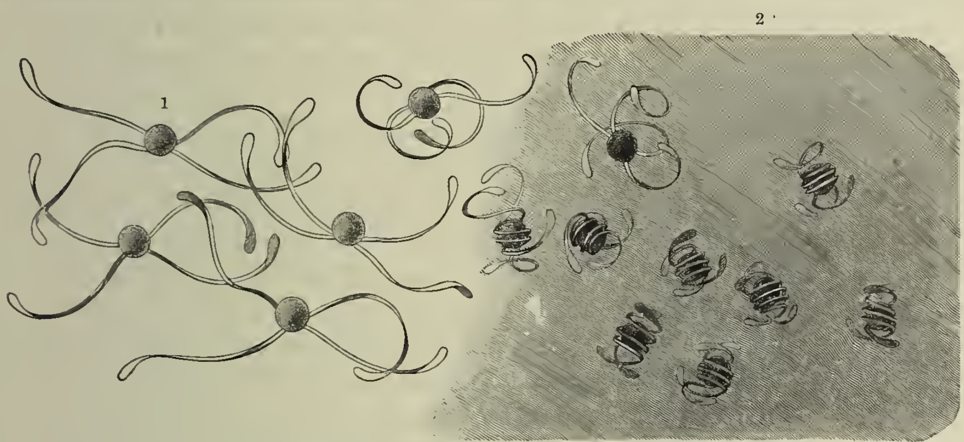


Fig. 451.—Spores of the Horse-tail *Equisetum Telmateja.*

[1] In dry; [2] in moist condition; ×25.

some spot of earth which, on account of its dryness, is not suitable for their germination the wings remain widely outspread. The next gust of wind raises them up again and carries them to another place. If, however, the resting-place is moist, and if the conditions are favourable to the growth of the *Equisetum*, the bands roll up spirally (see fig. 451 [2]). In this way the spores may become fastened to a projecting object, and if this should not be the case at least the rolling up of the bands produces a diminution in size, and the spores are not easily again blown away from a suitable damp resting-place. Another explanation as to the function of these structures has also been offered, namely, that by means of the repeated expansions and contractions of these hygroscopic arms the spores are linked together as it were arm in arm. Further reference to this will be found at p. 713.

The soredia of Lichens must also be mentioned as asexual reproductive bodies which are distributed in enormous quantities by currents of air. To the naked eye they look like a floury dust deposited in places on the Lichen thallus. These dusty masses are built up of green cells, either solitary or in groups, which are wrapped

round by colourless hyphal threads. They arise in the interior of the Lichen body, and are ultimately pushed out on the surface by the rupture of the pustules in which they arise. The wind raises and carries them away, and if they happen to fall into the cleft of a rock or into the crevices on the bark of a tree they immediately grow up into a new Lichen body which agrees in every particular with the parent plant and is itself able to again produce soredia. The genera *Stereocaulon*, *Evernia*, and *Pertusaria* are especially noted for their abundant formation of soredia. The shrub-like, branched *Stereocaulon coralloides* is often so thickly covered with soredia that the whole Lichen looks as if it had been strewn with coarse meal, and *Evernia furfuracea*, growing on the bark of old trees, owes its name to the fact that it seems to have been overstrewn with meal.

It has already been stated that the multicellular offshoots (gemmæ or thallidia) of Mosses and Liverworts may be distributed by wind as well as by rain-water. We might mention as examples, *Aulacomnion androgynum*, *Calypogeia Trichomanes*, *Scapania nemorosa*, *Jungermannia bicuspidata*, and *Blasia pusilla*, whose offshoots are borne on special erect supports (see figs. 196 [15, 16, 17, 18], p. 23), or *Syrrhopodon scaber*, which grows in Central America, and whose thallidia are formed on the apex of the leaflets (figs. 196 [12, 13, 14]). The Moss *Tetraphis pellucida* (figs. 196 [4, 5, 6]), which grows commonly on rotten tree-trunks in Pine forests in mountainous regions, might also be mentioned. It develops multicellular disc-shaped gemmæ at the top of certain erect shoots. The discs are supported on delicate filamentous stalks and are embedded in a cup of closely crowded leaflets (figs. 196 [5, 6, 7, 8]). After the supporting threads have withered and the small multicellular discs have become detached, a slight shaking by the wind is sufficient to make the gemmæ fall out and to scatter them. The same breeze which shook the stem now whirls the tiny green discs far over the forest ground and transports them to other places of attachment where they continue their development.

In some Mosses whose little leaves are very brittle when dry, for example, in *Campylopus* (see fig. 196 [11]), the leaves themselves serve as offshoots. How the detachment of these leaflets is brought about is to some extent an enigma; apparently they separate and are thrown off spontaneously, not unlike the foliage-leaves which fall from the branches of trees in autumn. This is immaterial to the question under consideration here, however. This much is certain, that in the remotest mountain ravines, and on inaccessible ledges in precipitous places where the disturbance of passing animals is quite impossible, the turf-forming crowded stems of *Campylopus* always carry detached and partially split leaflets which adhere loosely to the support. When after a few dry days a storm rages through the ravines, these loose leaflets are torn away, and do not again come to rest until they are far distant from the spot from which they were taken. The offshoots of Mosses composed of groups of cells, and the last-mentioned detached leaves which function as offshoots, do not grow up immediately into new Moss-plants, but first of all develop protonema-like cell-filaments, and it is from these that the young Moss-plants originate.

It also happens that whole Moss-plants with elongated axis, numerous leaves,

and abundant rhizoids are distributed by wind. This is observed in Mosses of very different genera (e.g. *Leucodon sciuroides, Thuidium abietinum, Hypnum rugosum, Myurella julacca, Conomitrium Julianum, Anœctangium Sendtnerianum*). The development of this form of offshoot is shown in figs. 156 [9] and 156 [10], p. 23, in *Leucodon sciuroides,* which is common on the bark of old trees. In the angles made by the leaves with the axis of old shoots, buds first arise which grow into miniature Moss-shoots. These tiny shoots then become loosened at their base, and push up towards the top of the leaves supporting them. This happens more especially in rainy weather. When it is dry their leaflets lie close to the axis, but when saturated with moisture they stand out and bend backwards, and thus raise themselves out of the deep niche in which they have hitherto been concealed. Many of these loosened shoots are without doubt carried away by rain-water, and so transported some little distance, but most of them are whirled off by the wind, and carried far away over mountain and valley.

Bud-shaped offshoots, which become detached from the aërial portions of plants, and whose distribution is effected by wind, are comparatively rare. A remarkable instance is furnished by the Club-moss *Lycopodium Selago* (see fig. 343 [2], p. 460). This plant, which is found in mountainous districts in the Northern Hemisphere of the Old and New Worlds, forms buds in the axils of its stiff, dark-green leaves, especially near the top of the shoot, which might, at first sight, be mistaken for small winged fruits. These buds are so provided with little leaves as to offer a good purchase to the wind, and by this means they are transported (*cf.* fig. 343 [5]). The North American *Lycopodium lucidulum, L. reflexum, L. Haleakala, L. serratum, L. erubescens,* behave in just the same way as *Lycopodium Selago,* and it is not improbable that many other allied species exhibit this kind of offshoot.

Most detached bud-like offshoots, which develop in the axils of foliage-leaves and bracts on larger plants, *e.g.* on the bulbiferous Coral-wort (*Dentaria bulbifera*; see p. 461), can hardly be said to be distributed by wind. They are spherical or ovate, and not flattened like those of the Club-moss, and they are too cumbrous for transport on the wings of the wind. And yet the wind plays an important part in the distribution in such cases. The bulbils are borne on fairly stiff shoots, and the nature of their attachment is very fragile. Thus, as the shoot rebounds after the blast, many of the bulbils become detached, and are jerked away to a considerable distance.

There are three types of offshoots which are jerked from the plant in the above-mentioned manner. First, those which have the form of closed buds or small bulbs, and which consist of a very much abbreviated stem or bulb-axis, and a few much-thickened scale-leaves filled with reserve materials. These are found in the bulbiferous Coral-wort, which grows commonly in Central European Beech forests, and has been selected as typical; on the bulbiferous Saxifrage (*Saxifraga bulbifera*), widely distributed in meadows in Eastern Europe; on several Lilies (e.g. *Lilium bulbiferum, tigrinum,* and *lancifolium*); and on the Persian *Gagea* (*Gagea Persica*), in the axils of the upper foliage-leaves; on *Foucroya gigantea,* growing on the

Antilles, and above the disc-shaped bracts on the top of the stalk on a considerable number of species of *Allium* (e.g. *Allium Moly, vineale, oleraceum, carinatum, arenarium, Scorodoprasum, sativum*). A second type, growing in the axils of bracts on the upper part of the stem, is shown by *Polygonum bulbiferum* and *viviparum*, natives of the far north, and of the Alpine regions of Europe and the Himalayas (see figs. 452 [1, 2, 3, 4, 5, 6, 7, 8]). These are not bulb-like structures, but small tubers or corms with a minute terminal bud projecting like a little horn, and the tissue of the tuber is abundantly filled with starch and other reserve materials (see figs. 452 [9] and 452 [10]). The third type is observed in species of the genus *Globba*, belonging to the Scitamineæ, more especially in the East Indian *Globba bulbifera* and in *Globba coccinea*, which grows in Borneo. These rare plants develop offshoots in the axils of bracts on the uppermost part of the rigid stem. They consist of a small bud, from whose minute axis a thick, fleshy root filled with reserve materials grows down, so that in reality the chief part of the offshoot consists of a root-structure.

When the closed bulb-like offshoots, tubers, or buds with thickened roots have been thrown from the wind-swayed stem they remain unaltered in the spot where they have found a resting-place through the whole winter, or the whole dry period of summer. At length, when the most suitable time of year arrives, little absorbent roots make their appearance (see fig. 452 [5]) at the expense of the stored-up reserve materials, and these fix the offshoots in the soil and convey fluid nourishment to them. The axis of the offshoot elongates and grows into a stem, putting out leaves and forming a new independent plant.

The entire sprouts, which are detached from aërial stems and become offshoots, can obviously not be transported very far by wind. They are much too heavy, and offer no suitable hold to the wind, which can only influence them by shaking the stem on which they are supported, or by rolling them along after they have fallen to the ground. In the former case the sprout-like offshoots are jerked off, and the action of the wind is therefore only indirect. Some plants bear side by side on the same stem tubers with undeveloped buds, and also some whose buds have begun to grow into sprouts, and have developed green foliage-leaves. These form a connecting-link between the groups just described and those we are now about to consider. One of them is the already mentioned viviparous *Polygonum* (*Polygonum viviparum*, fig. 452), in which it often happens that all possible stages of development occur close together on a single spike.

In Grasses especially it is often the case that the offshoots when ready to be detached have the form of developed, leafy sprouts. In the Grasses of the Arctic flora belonging to the genera *Poa, Festuca,* and *Aira,* the formation of leafy sprouts which become offshoots is so usual that in places the plants bearing offshoots are more common than those bearing flowers in their panicles. On our high mountains also there grows a grass (*Poa alpina, cf.* fig. 342 [8], p. 455), in which the panicles as often bear offshoots as flowers. On the plains of Hungary flourishes a species of Meadow-grass (*Poa bulbosa*), in which the same thing happens to such an extent that in the many thousand plants which cover the ground all the panicles develop

offshoots exclusively. The detachment takes place in different ways in these "viviparous" Grasses. Usually the sprouts loosen from the erect panicles of the

Fig. 452.—*Polygonum viviparum.*

[1] Entire plant; one spike bears flowers only, the other carries tubers on the lower half and flowers above. [2] A whole plant whose spike bears tubers only. On some of the tubers small foliage-leaves have already developed. [3-8] Fallen tubers in successive stages of development; nat. size. [9] A fallen tuber magnified. [10] The same in longitudinal section.

swaying haulm, and are scattered by the wind, but sometimes the separation does not occur until the stem is bent down to the ground with the weight of the crowded offshoots in the panicle. In this case the offshoots strike root where the panicle

touches the soil, and the result is that closely-crowded groups of new plants grow up round it. The same thing may be observed in *Chlorophytum comosum,* a native of the Cape often cultivated as a basket plant by gardeners under the name of *Cordyline vivipara.* In this plant leafy shoots are very regularly developed in the floral region instead of flowers, and as these increase in size and become heavier, the long, comparatively slender and very supple stem which bears them sinks down so that the sprouts are suspended on a green thread. If the ground below is suitable the pendent shoots which have meanwhile developed roots may settle there. If they do not come into contact with any suitable soil they remain a long time swaying in the air, growing and themselves forming long, thin stalks in their turn in whose floral region fresh, leafy sprouts with roots arise, and years after three or four generations of shoots connected together by a slender green stalk may be seen hanging down for the length of a metre. At length one or other of the swaying and wind-tossed sprouts strikes firm ground and takes root, separating itself from the old plant, or it falls like the fruit from a tree and rolls down below until it finds a place of settlement possibly at a considerable distance from the old plant.

Among the Rushes also there are many species which develop pendent sprouts. In one species which is very widely spread over Northern Europe, viz. *Juncus supinus,* it is much more usual to find sprout-like offshoots in the floral region than flowers. In many of the Saxifrages of the far North, viz. in *Saxifraga stellaris, S. nivalis,* and *S. cernua,* very reduced shoots with small rosettes of foliage-leaves are formed on the terminal branches of the floral axis, or bulb-like buds arise in the axils of the bracts on the upper part of the stalk which, like those of the viviparous *Polygonum,* send out green foliage-leaves before they fall or become loosened (see figs. 342 [1, 2, 3, 4, 5, 6, 7], p. 455). *Sedum villosum,* which grows on moors, develops short, leafy sprouts with thread-like axis in the axils of the stem-leaves. As soon as the stem begins to wither these sprouts loosen and are carried to a short distance by gusts of wind. They send out delicate roots as soon as they find a resting-place and new plants are established.

A very peculiar mode of detachment and distribution of sprout-like offshoots is found in many species of House-leek (*Sempervivum*). The *Sempervivum soboliferum* illustrated here may be taken as an example. The thick, fleshy leaves of this plant are arranged, as in all House-leeks, like rosettes on abbreviated axes, and the new rosettes are always laid down as minute buds in the axils of the rosette-leaves. From these buds proceed thread-like runners, furnished with small adherent scales, ending in a reduced shoot. The crowded leaves of this reduced shoot enlarge, forming a small rosette, the leaves being folded so closely together that the whole structure has a spherical form. For some time the round rosette is nourished by means of the filamentous runner from the old plant, but afterwards the runner withers and dries up and the rosette breaks away from it. It is now quite separated from the parent plant (see fig. 453). A gentle breeze is sufficient to roll along the small detached balls; and as the House-leeks in question choose

as their habitat narrow ledges in rocky places, it is inevitable that some of the separated rosettes should fall over the steep wall, and should not come to rest till they have travelled a considerable distance from the mother-plant. Roots are soon developed from the base of the detached rosettes, by which they become fixed to the substratum. Usually a parent plant produces 2–3 rosettes, but frequently as many as six, and the neighbourhood of the terraces overgrown with the species of House-leek figured, and with other allied species (*Sempervivum arenarium,*

Fig. 453.—*Sempervivum soboliferum.* On the lower step of the rock lie five ball-shaped offshoots which have become detached from the upper rocky platform and have rolled down. The butterfly and snail are introduced into the picture to show the true proportions of the offshoots.

S. Neilreichii, S. hirtum) often looks as if it had been sown with the ball-like rosettes, which have rolled down

Sedum dasyphyllum (see fig. 454 [1]), which grows in rocky crevices and in the niches of old stone walls, develops offshoots partly in the floral and partly in the foliage region. In the floral region the offshoots originate by the metamorphosis of floral-leaves into foliage. Instead of flowers there are small rosettes (fig. 454 [5]) of thick, ovate, green scales, like those which take the place of flowers in *Saxifraga nivalis* and *S. cernua* (*cf.* p. 455). These rosettes in the autumn break away from the flower-stalks, and behave just like those of *Sempervivum.* In the foliage region the offshoots arise in three ways. In the axils of the uppermost leaves there is formed a bud which is hardly perceptible to the naked eye. It is embedded in the

shallow depression on the upper side of the thick leaf, and possesses 2–3 leaflets about ·5 mm. in diameter (fig. 454[2]). In the axils of the lower foliage-leaves short sprouts are formed, whose axes are furnished with fairly large crowded rosette-shaped leaves (fig. 454[3]). In the axils of the lowest arise rudimentary sprouts, with an elongated thread-like axis bearing 8–14 thickly-crowded leaflets at its end (fig. 454[4]). As soon as the stem carrying the flowers begins to wither, the foliage-leaves and the buds or sprouts in their axils loosen from it and fall to the ground. The succulent, very turgid, almost hemispherical leaves are comparatively heavy, and if the spot where they first fall is sloping they do not lie still, but roll down until they are caught by some projecting ledge, or a mossy cushion, or arrive on level ground. Since they carry with them the buds and sprouts formed in their axils, they to a certain extent function as a means of transport. As soon as the offshoots come to rest, they develop rootlets at their base at the expense of the reserve materials of the detached succulent leaf. Rootlets are often formed even while the leaves are still adhering to the decaying stem. It is worthy of note that the aqueous tissue of the fallen leaves also plays a part in the establishment of these offshoots. If the spot where they have come to rest is exceptionally dry, as is usually the case in places where *Sedum dasyphyllum* grows, the supporting leaf may for a long time provide the water necessary for the maintenance of the offshoot, and so protect it from perishing.

Fig. 454.—The formation of offshoots in *Sedum dasyphyllum*.

1 Entire plant; nat. size. 2, 3, and 4, Offshoots which have developed at different levels on the stem in the axils of the leaves. 5 Offshoots from the floral region.

The formation of sprout-like offshoots is very remarkable in the Kleinias, natives of the Cape, which belong to the Compositæ. Some species of this genus, viz. *Kleinia neriifolia* and *K. articulata*, remind one very much in their appearance of certain Cacti. The fleshy, much-thickened cylindrical branches are connected with one another by thin strands, and the whole plant looks as if it had been constricted at intervals by ligatures. The strands joining the heavy cylindrical branches break at the slightest pressure, and the upper shoots especially may be broken off even by a violent gust of wind. The result of the fracture at the constricted places, however, is that the branches fall to the ground. If the plant grows on a slope, the fallen cylindrical shoots roll down until they are stopped by a projecting stone or some other obstacle. When they come to rest they develop numerous roots

where they touch the ground, and at the same time send up new lateral branches from the opposite side, as shown in fig. 455. It should be mentioned that in *K. articulata* the roots often begin to develop before the branches have broken and fallen off, always appearing on the side of the shoot which is turned towards the soil. This also is shown in the figure.

Fig. 455.—The formation of offshoots in *Kleinia articulata.*

In all these instances the offshoots are detached by the force of the wind. Another method by means of which the same end is attained depends on the hygroscopic properties of the tissues concerned, and on the alternate swelling and contraction from this cause. Several Fungi of the group Peronosporeæ, among others the unwelcome Potato-disease Fungus, *Phytophthora infestans,* multiply by spores formed on delicate hyphal threads, which are protruded from the stomata of the

host plant. These hyphal threads bifurcate, and the end of each branch swells up into a spore. The supporting hyphal branch then grows out again below each spore, elongates, and extends upwards, and pushes the spore on one side. The result of this oft-repeated process is a structure which resembles a small much-branched tree, with egg-shaped fruits hanging from the boughs. The hyphal branches, on which the spores are set like fruits, are cylindrical, stiff, and turgid in damp air, but in dry air, especially when they are ripening, they become ribbon-like and spirally twisted so as to resemble cotton-cells. They are extremely hygroscopic, and the slightest change in the humidity of the surrounding air is enough to increase or diminish their spiral torsion. Even mere breathing on them produces an alteration in the twisting, and if a rapid and marked alteration occurs in the hygroscopic condition of the environment, the branches with their hanging spores are whirled hither and thither, and the spores, which are only attached but slightly, are scattered in all directions. This cannot of course be seen except under unusually favourable circumstances, on account of the minuteness of the spores.

The shedding of the spores can be observed with the naked eye in the Mould *Pilobolus cristallinus*, one of the Mucorineæ, shown in figs. 456 [1] and 456 [2]. The mycelium of this Mould consists of a colourless, much-branched tube, and grows on the excrement of horses and other mammals. Enlargements arise on the mycelium, and from each is produced a sporangial mechanism composed of two parts, a colourless, barrel-shaped, stalk-cell and a dark head. The latter contains a colourless jelly, which swells up in water, together with numerous spores, and is to be regarded as a sporangium. Its wall is covered with calcium oxalate, so that its elasticity is completely lost and it becomes brittle. The cell-wall of the barrel-like swollen stalk, however, remains soft and elastic. At the junction of the dark sporangium with its colourless stalk a circular layer of separation is formed. When the turgidity of the sporophore increases in consequence of the absorption of water from the mycelium the tension at last becomes so great that it causes a rupture round the circular line mentioned. At the same moment, however, the elastic wall of the part of the sporophore immediately below contracts, and the fluid contents are pushed out with great force. The push is transmitted to the dark sporangium above the split, and both the fluid contents of the club-shaped support and the entire sporangium are thrown off (see fig. 456 [2]). The force of the explosion is so considerable that the dark mass is raised about a metre in height. The whole process, which, as we have said, may be seen with the naked eye, usually occupies 18–20 hours. The development of the mechanism begins at mid-day; during the night the spores are formed in the vesicle, and the next morning the explosion occurs as soon as daylight appears.

A no less interesting spectacle is afforded by the scattering of the unicellular offshoots, *i.e.* conidia, in species of the genera *Empusa* and *Entomophthora*. These live on the dead bodies of caterpillars, flies, aphides, and other insects, the commonest and best known being *Empusa muscæ*, which lives on the common house-fly. When a conidium of this *Empusa* falls on the body of the fly it puts out a tube which pene-

trates into the body-cavity, and there it divides up repeatedly, forming numerous cells throughout the body. The infected fly, sickening under the injurious influence of the Fungus and almost at the point of death, seeks for some quiet spot in which to die. It frequently chooses for its last resting-place a window pane, in which case it is possible to thoroughly investigate the further development of the Fungus. After the death of the fly the round cells of the *Empusa*, hitherto hidden in the body-cavity, grow out into long tubes which pierce the skin of the fly's corpse and appear as short club-shaped structures on the surface. A single egg-shaped conidium

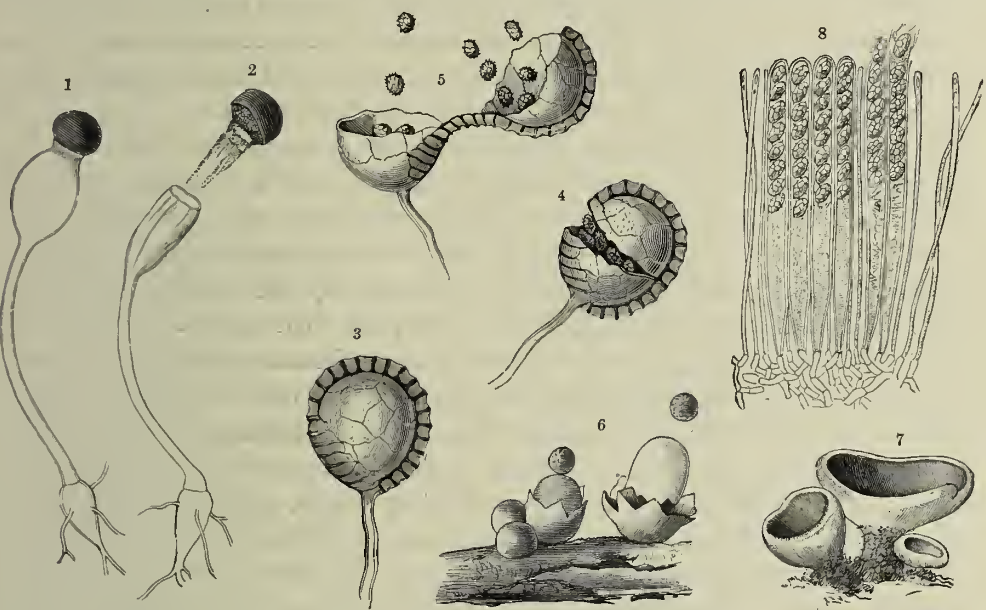


Fig. 456.—Distribution of spores by expulsive mechanisms.

[1] *Pilobolus cristallinus* before the sporangium breaks away. [2] The same at the moment when the sporangium is thrown off. [3] Sporanginm of *Nephrodium Filix-mas* closed. [4] and [5] The same in the act of splitting and scattering the spores. [6] *Sphærobolus stellatus* at the moment when the balls filled with spores are thrown off. [7] *Peziza aurantia.* [8] Longitudinal section through this *Peziza*. The spores are escaping from two of the asci. All the figures magnified

is then cut off from each club-like end of the tube, and this is thrown off in exactly the same way as the sporangium of *Pilobolus* (*cf.* fig. 383 [7], p. 672). Here, too, a place is formed for the splitting, and here again the mucilaginous contents are thrown off simultaneously with the conidium by the sudden contraction of the club-shaped end of the tube, and the conidium is thus always surrounded by a gelatinous adhesive mass (fig. 383 [8]). The distance of the projection may be as much as 2–3 cm., which, considering the extraordinary minuteness of the conidia, is proof of great power. The dead fly then appears to be surrounded by a veritable halo of detached conidia which are firmly attached to the substratum (fig. 383 [6]). This is to be accounted for by the fact that, as already stated, a part of the sticky mucilaginous contents of the club-shaped end of the tube are thrown out with the conidia. This serves as an adhesive material, and causes the conidia to adhere particularly firmly to glass window panes. If a living fly which happens to be near is struck by the projected

conidia, they stick to it so firmly that it cannot succeed in getting rid of them or freeing itself in spite of all its attempts. Each adhering conidium then again sends a tube into the body-cavity of the fly, and the development is repeated in the way just described. The same thing happens in *Entomophthora radicans*, which lives on the caterpillar of the Common White butterfly (*Pieris Brassicæ*). It is represented in figs. 383 [1, 2, 3, 4, 5], p. 672). Tufts of delicate thread-like hyphæ come out of the body of the caterpillar for the purpose of forming conidia (fig. 383 [3]). These gradually form a thick web round the dying caterpillar, and at a cursory glance one might think it had woven its covering and changed into a chrysalis (fig. 383 [2]). The tubes, looking like fine threads, unlike those of *Empusa*, are here much-branched, and actual tufts of hyphæ arise from whose ultimate somewhat swollen ends the long, sticky conidia are abstricted and scattered (figs. 383 [4] and 383 [5]).

The scattering of the spores from the asci of Ascomycetes takes place in a characteristic manner. They are developed in groups of 2, 4, 8, 16, or 32 in the tubular asci, and numerous thread-like hyphal ends, the so-called paraphyses, occur between the asci (see fig. 456 [8]). In addition to the spores the asci contain protoplasm and cell-sap, and are considerably distended by the large amount of the latter. As the dilatation increases the asci burst, and their cell-wall, which is at a high tension, exercises a powerful pressure on the cell-contents, which are extruded with great force. The place where the rupture of the wall of the ascus occurs is determined beforehand, so that the extrusion of the cell-contents and spores always takes place in the same way. In many species the top part of the ascus-wall is raised like a lid, in others a transverse splitting occurs, and in others again the spores are ejected through a small circular hole. A slight shake or a dry breeze is quite enough to cause the ejection, and in *Spatularia flavida*, for example (figured on p. 791), or in *Peziza aurantia* (see fig. 456 [7]), it is easy to observe how small clouds of extruded spores rise from the surface of the fructification as soon as these Fungi are brought from a damp place into a dry atmosphere, or when a dry wind blows over them. In some species of *Ascobolus*, minute black or waxen yellow Fungi living on the excrement of animals, the spores are not only ejected, but the turgidity of the tissue surrounding the tubes is so great that the whole tubular layer is extruded with the spores.

Some Gasteromycetes have special contrivances for scattering the spores. In species of the genus *Geaster* (see figs. 391 [4] and 391 [5], p. 690) the threads of the capillitium and the spores imbedded between them develop within a tough, leathery, bladder-like envelope which separates into two layers when the spores are ripe. The inner layer has the form of a bladder, and opens only at a spot at the apex. The outer layer, on the other hand, splits into 4–12 radiating lobes. The position of the lobes alters remarkably according to the hygroscopic condition of the atmosphere. In damp weather they fold together over the vesicle, but in dry weather, especially in sunshine and when a dry wind is blowing, they bend back so forcibly that some of the spores are shaken from the mouth of the vesicle. Travellers in Central America tell us of the gigantic Puff-balls which literally explode on being

shaken, sending such quantities of reddish spores into the air that it is impossible to breathe in their vicinity. In Europe a minute Puff-ball, *Sphærobolus stellatus* (fig. 456 [6]), grows on decaying stems, leaves, &c. The wall of the fruit divides, as in *Geaster*, into two distinct layers: one remains closed and assumes the form of a ball, but the outer one when the spores are ripe divides by radiating clefts into several lobes. These bend back rapidly on drying, and as the central portion round which the lobes are placed becomes strongly arched upwards, at the same time the ball containing the spores is shot out with considerable force.

The dissemination of spores in some of the Ferns is illustrated in figs. 456 [3, 4, 5]. Sporangia are developed on the under surface of the frond, where they are arranged in various ways. Those of the *Nephrodium Filix-mas*, which is here selected as a type, consist of a stalk and a flattened bi-convex vesicle. Round the latter runs a ring of darker-coloured cells, whose side-walls are much thickened, while their outer walls remain thin and delicate. When the sporangium is ripe its bursting is brought about by the contraction of the cells of the ring.

With regard to the distribution of offshoots by animals we may distinguish two classes, those in which the offshoots are first conveyed to the animals by special disseminating mechanisms, so that two methods of distribution are combined, and, secondly, those in which animals alone effect the transport of the offshoots from one place to another. We have already spoken repeatedly of the former class. Of the latter the distribution of spores by food-seeking animals is the first to be considered. The Pyrenomycetous Fungus known as the Ergot of Rye (*Claviceps purpurea*) is a well-known instance. The thick web of hyphal threads which invests the ovaries of the Rye is penetrated by labyrinthine passages, whose walls are formed by the ends of hyphal threads arranged in rows and tufts (see fig. 386 [2], p. 680). Spherical spores are abjointed from these somewhat club-shaped ends. Simultaneously with this abjunction the outer layer of the cell-wall of both spores and hyphæ forms a sugary fluid by the absorption of water and subsequent breaking down. This fills the winding passages, and the innumerable abjointed spores are imbedded in it. The sweet-tasting fluid gradually collects into drops on the exterior, and even comes into view on the spikes of Rye between the glumes which surround the infected ovaries. This is the "honeydew" by which the presence of the parasitic *Claviceps* in the interior of the spike is recognized, and which is viewed with some apprehension by the farmer. Insects, especially wasps and flies, eagerly seek out these springs of sweet fluid and suck and lick up the juice, which is crowded with numberless spores. It is therefore inevitable that small quantities of spores should stick and remain hanging to portions of their bodies, and when they fly to the spikes of other Rye-plants the spores are easily rubbed off, and in a very short time may again grow up into a mycelium involving the ovaries there.

A similar phenomenon may be observed in the Phalloideæ, belonging to the Gasteromycetes, of which the best known species, the Stink-horn Fungus (*Phallus impudicus*), may be taken as an example. The cap, borne on a white cylindrical and spongy stalk, is bell-shaped and covered with a greenish-black viscous fluid in

which numerous spores are imbedded. This fluid gives off a far-reaching carrion smell which allures many insects, especially carrion-flies. The fact that the fluid contains sugar which serves as nourishment for the insects also contributes to the allurement. A fly which alights on the cap of the Stink-horn cannot leave it without spores adhering to its whole body. Some of them may, perhaps, fall off while it is flying away, but the majority will not be brushed off until it again alights and cleanses itself from the uncomfortable appendages (*cf.* also p. 691).

It is well known that the fleshy fructifications of Hymenomycetes provide food for numerous insect-larvæ. Frequently as soon as the receptacles appear above the soil the flesh of the stalk and cap are riddled by passages in which live the larvæ of various gnats and beetles. These leave their dwellings before the decay and decomposition of the Fungi set in, and enter the chrysalis stage in the ground. In this way numerous spores which have adhered to the animals are carried away and disseminated. The spores of various Fungi, especially of the Hymenomycetes and Truffles, are without doubt distributed by animals which eat the fleshy spore-bearing portions. The spores pass unharmed through the alimentary canal and then germinate in the deposited excrement. Earthworms and swine in particular seem to take part in this distribution.

The dissemination of detached bud- and shoot-like offshoots is comparatively seldom effected by animals. Of the cases known the following are the most noteworthy. First, where the offshoots are taken up as food by animals, but are again got rid of in an undigested condition, and grow up into new plants in the place where they have been deposited. This has certainly been observed in *Polygonum viviparum*, which grows commonly in the far North and on the high mountains of Central Europe (see fig. 452). The bulbils of these plants are a dainty morsel to ptarmigan, and are eagerly sought for by them. The ptarmigan seizes the lower half of the spike of the Polygonum with its beak, and by a quick movement of its neck passes the bill the whole length of the spike, and so puts dozens of bulbils at a time into its crop. Numerous observations have shown that the bulbils of *Polygonum viviparum* and cranberries are the commonest food found in the crops of ptarmigan shot on the Alps, and I also always found these bulbils in great quantity in the crops of Norwegian ptarmigan. The portion which passes from the crop into the muscular gizzard is of course crushed and digested, but it has often been noticed that part of the food so greedily swallowed by the ptarmigan is thrown up again, and this is particularly the case with the bulbils when they have been taken in excess. When thus extruded, they have the power of further development; far from being destroyed, they grow up very rapidly into new plants, and as the places where the superfluous food is thrown out are always at some distance from the spot where the ptarmigan obtained the bulbils, this process is really a mode of distributing the *Polygonum viviparum*.

The second method of distributing detached offshoots by animals is effected by means of barbed bristles and hairs, such as are represented in fig. 457, in the Mamillarias (*Mamillaria placostigma* and *gracilis*) of the high mountains of Mexico.

Here some of the spherical, closely-crowded lateral shoots growing from the old plant loosen spontaneously and fall to the ground; others again remain *in situ* but adhere very slightly, so that a passing contact or a gentle touch is enough to complete the separation from the old plant. Now bristles are formed at the top of each papilla of these Mammillarias, some of which end in barbs, so that the spherical shoots resemble burs. They adhere just like burs to the hairy paws or fur of grazing animals, which carry them away unconsciously. Afterwards

Fig. 457.—Distribution of detached sprout-like offshoots by means of animals.
1 *Mammillaria placostigma.* 2 *Mammillaria gracilis.*

the animals when resting seek to rid themselves of the inconvenient appendages, brushing them off and leaving them behind on the ground. Here they may strike root and grow up into new plants.

The third method of distribution of sprout-like offshoots by animals is seen in aquatic plants, which fasten either entirely or in fragments to passing water-birds. Certain species, which very rarely blossom or form fruit, but nevertheless occur in innumerable widely distant spots and often appear unexpectedly in newly-formed ponds, in artificial lakes, and in other waters, are for the most part distributed by water-birds. Some of these water-plants, *e.g.* the Frogbit and Bladderwort (*Hydrocharis* and *Utricularia*), develop peculiar slimy coverings round their buds, which

cause them to stick to the feathers of birds which come in contact with them as they swim by. Others, such as the small Duckweeds (*Lemna minor, gibba, polyrrhiza*), hang by their long, somewhat twisted, floating roots, and many filamentous Algæ, *Aldrovandia*, the delicate Riccias (*Riccia natans* and *fluitans*), the Ivy-leaved Duckweed (*Lemna trisulca*), &c., become attached in their entirety to the coot and duck swimming in the ponds and lakes. These fly away with them, but as soon as they again enter other water the adhering plants fall off or are cleaned off by the birds, and in this way they are distributed quite fresh and living over great distances. We might also mention in this connection the peculiar distribution of Ulvas, Florideæ, and Sea-wracks by means of crabs, which was described at vol. i. p. 77.

We will only allude in passing to the fact that many economic plants are propagated and distributed by offshoots to a very great extent by man. Bananas whose fruits contain no fertile seeds, Potatoes, Artichokes, and many other tuberous and bulbous plants are continually multiplied by the help of slips, tubers, bulbs, &c. The intentional artificial propagation by offshoots has of course no apparent influence on the development of a natural method of distribution in such species. Although planted and cultivated in large quantities they do not become naturalized; and if it were not for the artificial maintenance and propagation by offshoots they would soon vanish again from such places, leaving no trace behind. This is, however, not the case with the unintentional distribution of offshoots of certain plants by man. The keels and bottoms of ships journeying over wide seas become, like the stakes and buoys of the harbour and the sea-walls and rocks of the shore, quite overgrown with sea-weeds. If these are removed by chance or intentionally from their substratum they do not necessarily perish. They may remain alive in the sea-water, and under favourable conditions may attach themselves to some other firm spot of ground. In this way plants may be transmitted from one coast to another over very wide distances. Another unintentional distribution of plant-offshoots by man occurs on cultivated ground in vineyards, fields, and gardens. By ploughing, digging, and throwing up the soil the bulbous or tuberous offshoots embedded in the ground undergo a change of position. The offshoots of certain plants may in this way be distributed so uniformly over a whole field by spade and ploughshare in the course of a year that it almost looks as if they had been purposely planted there. It is curious on journeying through the vine-planted districts of Northern Italy to see one of two adjacent vineyards abundantly covered with wild Tulips, while not one is visible in the other. In Central Europe the same thing happens with the Gageas (*Gagea arvensis, G. stenopetala*) growing in the fields, and with the tuber-forming Earth-nut pea (*Lathyrus tuberosus*). One field looks as if it had been sown with Gageas and yet its neighbour is completely devoid of them. On the Günselhöhe in the Lower Austrian Erlafthal I once saw a rectangular ploughed field overgrown from one end to the other with plants of the Bulbiferous Lily (*Lilium bulbiferum*), while only isolated specimens of this plant could be seen in the adjoining fields. There is no doubt that here the bulbils thrown on to the ground from the

leaf-axils of a few plants had been distributed equally by ploughing over the whole field, although this distribution had certainly not been intended by the ploughman,

It would of course be a mistake to explain the uniform distribution of bulbous plants over a large stretch of land exclusively by the ploughing and overturning of clods of soil full of bulb-like offshoots. In many instances the distribution of such offshoots is also produced by the pulling action of the roots. This process is so remarkable that we must describe it somewhat in detail. The multiplication of subterranean bulbs is known to take place by the formation of buds in the axils of the scale-leaves, and these, in the course of a few months, themselves grow up into small bulbs. When mature, they may form the termination of a slender shoot which, of course, never attains any considerable length, but which in many cases is thread-like, as shown in *Muscari racemosum* (fig. 444 [1]). The small bulbs are pushed by this thread-like shoot out of the region of the protecting scale-leaf near the old bulb, and there they develop long root-fibres in abundance. In other instances the shoots remain extremely short, and the small bulbs are not pushed out, but the protective scale-leaf, in whose axil they originated, decomposes, and they send out their roots through the decomposing tissue into the surrounding soil. In both cases they become detached at the end of the vegetative period in which they originated; they are then no longer connected with the old bulb, but are quite independent. Many species form only one bud in the axil of a bulb-scale, others a whole series which all grow up into bulbs; in the latter case the old bulb in the autumn is surrounded by a whole family of small young bulbs. There is a species of Garlic called *Allium pater-familias* whose old bulb gives rise to about a hundred young ones in a year. It is impossible for so many to develop properly when closely crowded together round the plant from which they sprang; mutual pressure would be unavoidable in their further growth, and if next year each of these bulbs should in its turn form new offshoots, and again become the centre of young bulbs, it would become imperatively necessary to make room, and to thin and separate the dense crowd. Since all the bulbs are placed with their apices pointing upwards they cannot be moved apart by the elongation of their stems; the mutual pressure of neighbouring bulbs as they enlarge would certainly cause a trifling displacement, but this would not prove an efficient remedy. The remarkable pull of the roots, which was described in vol. i. p. 768, now comes into play. Only a few of the roots arising from the base of a young bulb strike downwards; by far the greater number grow out at a right angle to the axis of the bulb in a direction parallel with the surface of the soil (see fig. 444 [1]). When these very long roots have stopped growing they contract, and thus draw the young bulb to which they belong away from the old one. The young bulbs now form a wide open wreath round the old one (which has meanwhile disintegrated), and thus obtain sufficient room for further development. This happens not only in the *Muscari* described, but also in *Ornithogalum nutans, Tulipa sylvestris,* and indeed in quite a number of bulbous plants. Since this process is repeated annually a fairly wide area of soil may in the course of years be covered with the bulbs in spite of the slight distance through

which they have been shifted under the ground. Some soil containing bulbs of *Tulipa sylvestris* was once put in a garden in Vienna in the middle of a grass plot shaded by Maple-trees. As the grass was mowed every year before the flowers opened there was no formation of seed, and the Tulips could only multiply by offshoots. After about 20 years the lawn was covered with Tulip-leaves, which arose from subterranean bulbs occupying an area 10 paces in diameter. Thus in the time mentioned the bulbs had spread for about 5 paces in all directions, in consequence of the pull of the contracting roots. It is more than probable that the offshoots of many perennial plants with erect stem and napiform or tuberous roots, *e.g.* the blue-flowered species of the Monkshood (*Aconitum Napellus, A. Neubergense, A. variegatum*) undergo a change of position by the pull of their horizontal root-fibres; and that the clustered arrangement of these plants is the result of the root-pull.

A review of the very varied modes of origin and distribution of offshoots leads to the conclusion that they may be formed on all parts of the plant, that the form of the offshoot is constant for each species, or, in other words, that the form of the individual parts of the offshoot in succeeding generations is repeated as exactly as the flowers and fruit, but that one and the same species may frequently form two or even three kinds of offshoots. The Fungus *Claviceps purpurea* develops spores which are distributed by honey-sucking insects, also the sclerotia known as "ergot", which are scattered from the dry spikes by the swaying movement of the stem, and thirdly, filamentous spores, which are extruded from asci, and distributed by wind. The Liverwort *Blasia pusilla,* develops thallidia in special flask-shaped receptacles on the surface of the thallus, and spores in the sporogonia. The form of the offshoot is always adapted to the season and to the distributive agents available where they are formed. In one case it is more suitable that the offshoots should be distributed slowly, and step by step, in another quickly and by bounds. In the spring it may be more advantageous if they are distributed by wind, by animals in the summer, and by self-scattering mechanisms in the autumn. Steppe-plants must develop different offshoots from those formed by plants living on the damp, shady floor of the forest. It is just as obvious that offshoots, which creep along, above, or under the ground without leaving the soil, must be equipped quite differently from those which are detached from their place of origin, and either roll along or are carried by wind, or have to travel long distances as the appendages of wandering animals. In the former, it is all-important that they should be able to overcome possible obstacles in the soil; in the latter, that they should not perish during their journey for lack of food and water. When separated from the soil they are greatly exposed to the danger of drying up, and even when they have settled somewhere, the supply of water they require for the formation of organs of attachment and absorption is by no means assured. Settlers of this kind must either be so organized that they can sustain a long-continued drought without injury, like the offshoots of the Mosses and the soredia of Lichens, or they must themselves bring with them the necessary water supply, and care must be taken

that this supply is not lost prematurely by evaporation. As a matter of fact, such detached offshoots, *e.g.* those of *Sempervivum, Sedum, Kleinia,* or *Mamillaria,* are not only provided with a special aqueous tissue, but also with a cuticle which is very effective in preventing excessive transpiration. All offshoots, when liberated from their place of origin, are also provided with the necessary reserves, *i.e.* constructive materials, so that immediately after settling, they can send out absorbent roots and green leaves of their own initiative, obtain a firm footing in their new locality, and extract nourishment from it. When the offshoots are distributed by water-currents, they require neither an aqueous tissue nor protection against drying up, and it may be due to this fact that detached offshoots are relatively more frequent in aquatic than in land plants and lithophytes.

THE DISPERSION OF SPECIES BY MEANS OF FRUITS AND SEEDS.

On the heights of the Kahlenberg, at Vienna, at the edge of the wood, grows an under-shrub which bears the name of *Dorycnium herbaceum.* It is one of the Papilionaceæ, and develops spherical one-seeded fruits, which ripen in October. I once collected from this plant several twigs laden with fruit, for the purpose of a comparative investigation on which I was engaged, and brought them home and laid them on my writing-table. Next day as I sat reading near the table, one of the seeds of the *Dorycnium* was suddenly jerked with great violence into my face. Shortly afterwards I saw a second, third, fourth, and ultimately about fifty seeds let fly from the small clusters of fruit, and each time I heard a peculiar sound which accompanied the bursting open of the fruits and ejection of the seeds. The rays of sunshine from the window had evidently heated and dried the fruits, and occasioned this surprising phenomenon. The incident reminded me of the following passage in Goethe's *Travels in Italy*:—"I had brought home several seed-capsules of *Acanthus mollis,* and put them away in an open box, when one night I heard a crackling noise, and immediately afterwards a sound like the impact of small bodies against the walls and ceiling. I could not understand it at first, but found afterwards that my pods had burst and scattered their seeds all over the place. The dryness of the room had caused the fruits to ripen in a few days to the requisite degree of elasticity."

The fruits of *Dorycnium* and *Acanthus* may be taken as types of a large group designated by the name of Sling-fruits. It is found that when these fruits are ripe, the tissue around the seeds becomes highly tense. The first result of the tension is that the tissue is rent at particular spots, and this rupture is followed by a sudden contraction of the segments, which double back and roll up, at the same time expelling the seeds resting upon them. Sometimes the rolled parts of the fruits, and, more rarely, the entire fruits themselves, are jerked off simultaneously with the seeds. There is the greatest variety in this respect, but all the contrivances for expelling seeds resemble one another in the fact that through their agency the seeds reach places beyond the range of the mother-plants.

In one class of expulsive fruits the high degree of tension which finally results in the disruption and rolling up of particular tissues is caused by a swelling up of the cell-membranes or by the turgidity of the cells. One of the most curious instances is that of the Squirting Cucumber (*Ecballium Elaterium*), which is shown in fig. 458 [1]. This plant belongs to the Cucurbitaceæ and its fruit resembles a small fleshy cucumber beset with bristles and borne by a hooked stalk. The end of the stalk projects into the interior of the fruit like a stopper. When the seeds are quite

Fig. 458.—Sling-fruits.

[1] *Ecballium Elaterium*; branch bearing flowers and fruits. [2] A fruit detached from its stalk and with its seeds squirting out. [3] *Oxalis Acetosella*; entire plant with one unripe fruit on a hooked stalk, and one ripe fruit on an erect stalk ejecting its seeds; nat. size. [4] Unripe fruit of *Oxalis Acetosella*; ×6. [5] Ripe fruit of *Oxalis Acetosella* ejecting the seeds; ×6.

ripe the tissue surrounding them is transformed into a mucilaginous mass. Also the tissue in the neighbourhood of the conical stopper just referred to breaks down at the same time, and thus the connection between the stalk and the fruit is loosened. In the wall of the fruit there is a layer of cells which is under great tension, and endeavours to stretch itself out. As long as the fruit is unripe such expansion is prevented by the tense tissue close to the stalk, but with the ripening of the fruit this obstacle is removed. The fruit then severs itself from the conical end of the stalk and at the same moment the expansion of the strained layer of tissue takes place. The consequence is that the interior of the fruit is subjected to great pressure, and the seeds, together with the surrounding mucilage, are squirted out

with considerable force through the hole which was previously closed by the end of the stalk (see fig. 458 [2]).

The Dorsteniaceæ behave in a manner no less remarkable. As in the case of Figs so also in these plants, numbers of small flowers are seated upon an enlarged receptacle, which remains fleshy and succulent after the small one-seeded fruits have developed from the flowers. The lower portion of each fruit has thick walls, and is embedded in the receptacle like a hair-follicle in the human skin, whilst the delicate-

Fig. 459.—Sling-fruits.

1 *Orobus vernus.* 2 and 3 *Geranium palustre.* 4 *Viola elatior.* 5 *Cardamine impatiens.* 6 *Impatiens Nolitangere.* 7 and 8 *Acanthus mollis.* 9 and 10 *Ricinus communis.*

coated portion projects above the receptacle in the form of a papilla. When the seed is quite ripe the turgidity of the outer cellular layer of the thick wall of the fruit increases, the thin-walled top is torn, the thick walls suddenly close, and the seed hitherto enveloped by them is violently ejected.

A special case of the expulsion of seeds as from a sling is also found in Oxalidaceæ, of which the common Wood-sorrel (*Oxalis Acetosella,* see figs. 458 [3, 4, 5]) may be taken as an example. In this case it is the seed-coat that possesses a special tumescent tissue adapted to the expulsion of the seeds. One of the deeper layers of the seed-coat is composed of tense cells and is itself in a highly strained condition,

whilst the outer layers of cells of the seed-coat are not in a state of tension. When the seed is quite ripe the cell-membranes in the strained layer of tissue swell up, the outer layer of the seed-coat, being no longer able to withstand the pressure to which it is subjected, is rent asunder and the edges of the slit thus formed roll suddenly back. A violent jerk is given to the inclosed seed, in consequence of which it flies out through the fissure in the capsule immediately in front of it (fig. 458 [5]). The fact of the ejection of the seeds of Balsamaceæ also has long been known. The fruit of *Impatiens Nolitangere,* one of the members of that family, is an oblong capsule composed of five carpels (see fig. 459 [6]). The walls of this capsule are constructed of three layers of cells. The layer lying immediately beneath the epidermis consists of large and highly turgid cells, and is called the turgescent layer. It is in a state of great tension, and when the seeds are ripe and the union between the five carpels gives way along the lines of union, a relaxation of the tension takes place, the loosened tissue of those lines is torn, the five carpels roll up, and their rapid movements of involution result in the expulsion of the seeds contained in the fruit. *Cyclanthera explodens* and *Thladiantha dubia,* plants belonging to the Cucurbitaceæ, as also several Crucifers of the genera *Dentaria* and *Cardamine,* in particular the species shown in fig. 459 [5] (*Cardamine impatiens*), exhibit similar phenomena, except that in these cases the carpels do not roll inwards but outwards.

In the instances hitherto dealt with the cause of the expulsion is the turgidity of cells or the swelling up of cell-membranes with a concomitant maintenance of a state of extreme tension in a particular layer of tissue situated in the wall of the fruit. In the next class of cases the phenomenon depends on the desiccation and consequent contraction of a special layer of the fruit-wall which leads to a rupture and subsequently to a bending over and rolling up of particular parts of the fruit. This change is accomplished with great rapidity and has the effect of hurling away the seeds or the separate parts of the fruit or even the entire fruit itself. We will only mention some of the best known instances of this kind.

The fruit of the Marsh Crane's-bill (*Geranium palustre*; see fig. 459 [2]) has a 5-angled column rising up in the centre of a circle of five carpels. The carpels are hemispherically inflated at the base, and terminate above in long bristles or beaks. Each contains a single seed. When the seeds are ripe, the tissue composing the beaks undergoes desiccation, which, however, is not of uniform intensity throughout. The outer layer, consisting of several plates of succulent cells, dries up more quickly than the inner layer, which is composed of thick-walled cells. The result is that the beak lifts itself away from the axial column, and curls up externally like a watch-spring. No resistance to this movement is afforded by the delicate dried tissue which has hitherto served to hold the carpels together, and as the cavity of each carpel is open along the inner surface, and the seed lies in it simply as though it were resting in the hollow of a hand, the rapid drawing up of the beak has the effect of ejecting it in a wide curve away from the carpel (see fig. 459 [3]). In the Marsh Crane's-bill, as also in the other large-flowered species of the genus *Geranium,* the tops of the beaks continue attached to the axis, and the latter, together with the five

empty and rolled-up carpels, resembles a chandelier in shape (shown to right of fig. 459 [3]).

Those Violets which have aërial stems, such as *Viola elatior* (see fig. 459 [4]), develop capsular fruits, each of which resolves itself into three valves when it bursts open. The valves are boat-shaped, and the marginal parts which form the sides of the boats are thin, whilst the keels are very thick and swollen. Inside each boat, near and parallel to the line of the keel, are two rows of seeds. The valves themselves have an exceedingly complex structure. A cross section through one of them shows a layer of thin-walled parenchymatous cells, a layer of elongated curvilinear cells, and a layer of broad, greatly thickened cells. The unequal desiccation of these layers is the cause of the curving up of the lateral walls of the valves, which at last approach so near to one another as to exercise considerable pressure on the seeds in the middle. The result of this pressure is that the smooth seeds are shot out with about the same force as is imparted to a cherry-stone when it is flicked to a distance by the finger and thumb. The seeds are ejected in regular succession. The foremost seed of the first carpel goes first, and the seeds at the opposite extremity are discharged last. It is not till the first carpel is quite empty that the second begins to part with its seeds, and the third only comes into play when the second is finished. The drawing together of the two sides of the valve always begins at the free extremity of the valve, and lasts until all the seeds have been ejected.

In many Mimoseæ, Cæsalpineæ, Papilionaceæ, Sterculiaceæ, and Acanthaceæ the seeds are expelled by means of a spiral torsion of the valves of the fruit at the moment that the legume or capsule opens. The wall of the fruit of these plants includes a soft succulent layer of thin-walled parenchymatous cells, and a hard layer of strongly-thickened elongated cells, which run obliquely from one edge to the other in each valve. The rupture of the fruit, and the spiral torsion of its valves at the moment of their separation, depend upon these diagonal cells of the hard layer. Each one of these cells winds itself into a spiral as it dries, and consequently the entire layer undergoes a corresponding torsion. The tissues composed of thin-walled cells, which are in connection with the hard layer, offer no resistance to the movement, and the rotation is therefore so sudden and violent that the seeds contained in the pod are projected to a distance. If the fruit is short, the valvular torsion is confined to ½–1 twists; if long, the spiral includes 2 or even 3 complete coils, and the valves of the empty fruit are curled up like ringlets (e.g. *Lotus corniculatus*, see p. 431, fig. 325 [3], and *Orobus vernus*, see fig. 459 [1]). The force of projection varies according to the thickness of the hard layer. In *Castanospermum australe*, where the pod-valves attain to a thickness of 5 millimetres, the sudden torsion causes the expulsion of spherical seeds, measuring 3·5 centimetres in diameter, and weighing 16 grams. In these cases the valves of the fruit persist upon the fruit-stalks after the ejection of the seeds, and herein lies the essential difference between them and those expulsive fruits of which the carpels break away from the stalks with the seeds. To this class of expulsive fruits belong also several Papilionaceæ, such as the *Dorycnium* mentioned at the beginning of this section, and besides them the genus

Kitaibelia of the family Malvaceæ, *Alstrœmeria* amongst the Liliaceæ, several Acanthaceæ, including the *Acanthus mollis* (see figs. 459 [7] and 459 [8]), which Goethe has made familiar to us, the wonderful parasite, *Lathrœa clandestina*, and many Euphorbiaceæ (e.g. *Euphorbia, Hura, Hyænanthe, Mercurialis, Ricinus*, see figs. 459 [9] and 459 [10]). In all these plants the fruit-valves are comparatively short, and the spiral torsion is therefore less clearly manifested. The impulse given to the seeds by the twisting of the valves is supplemented by various other contrivances which cannot here be described, and, as a matter of fact, the range of projection in this group of sling-fruits is wide as compared with that of others.

A peculiar form of sling-fruit is found in several of the Diosmaceæ, Rutaceæ, and Zygophyllaceæ. In these plants a complete separation of the hard from the soft layer takes place. When the seeds are ripe the external soft layer dries, splits along the ventral suture, and contracts strongly. In consequence of this contraction the hard internal layer, which is in the form of a case inclosing the seeds, is forced out of the slit. As soon as the hard case is thus set at liberty its two lateral walls part asunder, assume the shape of the screw of a steamer, and eject the seeds to a distance. Similar processes occur in the genus *Collomia* of the family Polemoniaceæ, but in this instance it is not the soft outer layer of the valves but the calyx, which, on drying, exercises pressure on the inclosed case, and the latter, which is extruded, is not the hard layer only but the entire dry capsule. The liberation of the case is here materially assisted by the circumstance that the three valves of the capsule disunite at a time when they are still surrounded by the calyx, and hence exert a counter-pressure upon the calyx. When once the capsule is freed from the grasp of the calyx, its valves diverge still more widely from one another and eject their seeds. In *Eschscholtzia* also the entire fruit is jerked off the receptacle, but here the phenomenon depends on the fact that the two valves of the siliquose fruit attain to a high degree of tension on desiccation and tend to curve outwards. When the tension has reached a sufficient pitch to sever the connection between the fruit-valves and the receptacle, the whole fruit is shot away from the stalk in a curve. In the Stork's-bill (*Erodium*, see vol. i. p. 619, figs. 147 [3] and 147 [4]), and in several Umbellifers (e.g. *Scandix*), the entire fruit is not thrown off, but the constituent parts of the fruit with their tightly inclosed seeds are jerked away from the central axis.

This cursory survey is sufficient to give an idea of the great variety existing amongst the sling type of fruit. Of course the fruits in question are always placed in such a position as to render a free flight of the seeds possible. In every case where the fruits before ejecting their seeds or being themselves jerked away are for any reason hidden under foliage-leaves, or are borne by stalks which bend downwards, as in the Wood-sorrel and the Violet (see figs. 458 [3] and 458 [4]), the stalks straighten out just before expulsion takes place and lift the fruits up above the leaves. In most instances the angle of projection is 45°, and, as is well known, the greatest range of flight is thus attained. The ejected seeds are spherical, oval, bean-shaped, or lenticular. In the last case they are expelled in such a manner as

to cut edgewise through the air, and it is the invariable rule for seeds to be so ejected as to encounter as slight a resistance from the air as possible whatever their shape may be. Contrivances for determining the direction in which the expelled body is to move are rare. A first indication of some such adaptation occurs in the Wood-sorrel (see fig. 458 [3]) and in *Ricinus* (see fig. 459 [10]), where the seeds are thrust through an opening of definite shape. In the Acanthaceæ (*Justicia, Acanthus,* &c.), the path of projection is determined by the circumstance of the seeds resting before their expulsion against rigid curved bars springing from the partition-wall which runs through the fruit (see fig. 459 [8]). The act of expulsion is usually accompanied by a characteristic noise like that of the bursting of a bladder, and the sound amounts to a regular detonation in the case of the dehiscence of the fruits of *Hura crepitans.* The range of projection is least when the seeds are small and light, and greatest when they are large and heavy, as is shown by the following table:—

Name of Plant.	Shape of Seed.	Longest Diameter of Seed in Millimetres.	Shortest Diameter of Seed in Millimetres.	Weight of Seed in Grams.	Range of Projection in Metres.
Cardamine impatiens	ellipsoidal	1·5	0·7	0·005	0·9
Viola canina	oval	1·6	1·0	0·008	1·0
Dorycnium decumbens	spherical	1·5	1·5	0·003	1·0
Geranium columbinum	spherical	2·0	2·0	0·004	1·5
Geranium palustre	cylindrical	3·0	1·5	0·005	2·5
Lupinus digitatus	cubical	7·0	7·0	0·08	7·0
Acanthus mollis	bean-shaped	14·0	10·0	0·4	9·5
Hura crepitans	lenticular	20·0	17·0	0·7	14·0
Bauhinia purpurea	lenticular	30·0	18·0	2·5	15·0

It will be noticed that as a means of distribution the agency of expulsive fruits is confined to a very restricted range. As compared with the distances to which seeds are conveyed by other means, such as the wind, the range of projection of the most powerful contrivances for expulsion, viz. 15·0 metres, is inappreciably small. This may account for the facts, firstly, that expulsive fruits are produced by comparatively few plants; and secondly, that such plants as do possess them are for the most part denizens of localities that are sheltered from the wind, where, therefore, the conditions are not favourable to dispersion by that agency. *Cardamine impatiens, Dentaria, Impatiens, Lathræa clandestina, Mercurialis perennis, Orobus vernus, Oxalis Acetosella, Viola canina,* and *V. sylvatica* all inhabit retired and shaded woodlands, whilst others, as, for instance, *Geranium palustre* and *Lathyrus sylvestris,* climb over bushes and hedges on the borders of woods. Mention must also be made of the fact that in many cases a second mode of dispersing fruits and seeds acts conjointly with that of expulsion, as is indicated by the name of *Impatiens Nolitangere, i.e.* "Touch me not". Those sling-fruits, for instance, in which the high degree of tension is due to the swelling up and turgidity of particular layers of cells, are so constructed that the slightest touch on the outside causes a relaxation of the tension and the ejection of the seeds in the direction of the object that has touched the fruit. The animals which frequent the shady woods

where *Impatiens, Cardamine, Dentaria, Oxalis,* &c., grow, brush against the fruits of those plants in the course of their wanderings, and at once receive a charge of seeds, some of which are sure to be left sticking to the creature's fur or feathers. It has long been known that when animals pass over places that are overgrown by *Elaterium* (see fig. 458[1]) and brush against its fruits, which hang down from hook-shaped stalks, they are bespattered with the mucilaginous mass in which the expelled seeds are embedded, and that as soon as they reach a place of rest they endeavour to get rid of the unpleasant encumbrance.

Several contrivances for the distribution of fruits and seeds remain to be described which, so far as regards their results, exhibit the greatest resemblance to the above sling-fruits, although the causes which determine the phenomenon in their case are utterly different. In the last-named the forcible expulsion is due to cellular turgescence, or to movements brought about by the drying up of hygroscopic cell-layers; in the cases now to be described the result depends solely on the elasticity of stems and fruit-stalks. The stems and stalks in question are strongly resilient, and are strained and curved by a force acting from without. The moment the force ceases to act, their quality of resilience causes them to return to their former position, and in doing so they jerk the fruits and seeds borne by them to a distance. Of these contrivances, which are called balistic means of dispersion of fruits and seeds owing to their analogy to catapults or balistas, we will here deal with five forms. The simplest occurs in the Compositæ, whose fruit-capitula are borne upon erect, comparatively long, elastic, flexible stems. The small fruits of the capitulum are already detached from their short pedicels by the time they are ripe and are deposited upon the central disc of the receptacle, which is surrounded by involucral scales, or at the bottom of the basket-shaped fruit-capitulum into which the floral-capitulum develops. They are so deeply bedded in this situation that it is not possible for them to fall out unless subjected to some external impetus. But the erect resilient stem which bears the capitulum has only to be bent to one side by a gust of wind or by the touch of an animal for the fruits lying on the fruit-capitulum (which is flat or excavated as the case may be) to be shot off by the recoil which ensues. In many of the Compositæ the involucral scales which form the enveloping basket bend towards one another at the top so as to constitute a roof; they are, however, elastic and flexible and very smooth on the inner surface, so that the fruits when ejected easily slip by them, and yet are to a certain extent guided in the course they take by the tips of the scales. In other Composites, of which the genus *Telekia* is an example, the floral receptacle is thickly clothed with so-called paleæ, and the fruits to be ejected, which, it may be noted incidentally, have no pappus, are embedded amongst these paleæ. The paleæ are erect and stiff, and are edged with small, upturned teeth; the slightest shock sends the fruits a little higher up amongst the scales, and they cannot then return to their former position, as the stiff marginal teeth bar the way. The fruits thus seem to make their way up the scales, step by step, as though they were ladders. If, when they have nearly reached the top, there comes a gust of wind which sets the peduncles of the capitula

rocking to and fro, the fruits are thrown out from between the elastic tips of the scales and describe an open curve before they reach the ground. A third group of Composites, which may be represented by *Centaurea Pseudophrygia* and *C. stenolepis*, exhibits the following arrangement: The receptacle is destitute of paleæ, but the involucral scales form a sort of basket at the bottom of which are the fruits. In damp weather the tips of the bract-scales close tightly together, and the short bristles of the pappus crowning each fruit are applied closely to one another. In warm, dry weather especially, under the influence of a dry wind and sunshine, the scales part asunder and the basket stands wide open. At the same time the hairs

Fig. 460.—Catapult fruits.

1 and 2 *Salvia verticillata.* 3, 4, 5 and 6 *Teucrium Euganæum.* 7 and 8 *Teucrium flavum.* 9 *Monarda fistulosa.* 10 and 11 *Polygonum Virginicum.* 1, 8 and 10 nat. size; the others magnified.

of the pappus bristle up, and in so doing raise the fruits to the open mouth of the basket. If the peduncle supporting the capitulum is now set in motion, the fruits are tossed out like shuttle-cocks. The bristly pappus-hairs are not in this case organs of flight; they are short and stiff, and, besides raising the fruits, serve also to determine the direction of their fall. Balistic apparatus very similar to that just described is also found in several *Iridaceæ, Liliaceæ, Caryophyllaceæ, Primulaceæ,* and *Scrophulariaceæ,* only in them the erect, resilient stem does not bear a fruit-capitulum but a capsule, and the ejected particles are not fruits but seeds. The seeds are comparatively large and heavy, and are destitute of membranous or hairy appendages. In all these cases the capsule is situated with its orifice upwards and only opens in dry weather. As its cavity is very deep, no ejection of the seeds ensues except when the resilient stalk which carries it sways somewhat violently to and fro.

The manner in which the fruits of Labiatæ are thrown off is particularly remarkable. The fruits in question are spherical, oval, or ellipsoidal nutlets, and when ripe are still hidden at the bottom of the persistent calyx. The calyx is either bell-shaped or tubular, and faces laterally; the pedicel supporting it is resilient, and usually bowed (see figs. $460^{1, 2, 3, 6}$). If one presses upon the stiff points of the calyx with some hard object such as a piece of wood (fig. 460^{5}) the pedicel is subjected to a strain, and as soon as the pressure ceases it springs back to its former position, and the nutlets are shot out with great force (fig. 460^{6}). The path of projection is in this case determined by the two inferior calyx-teeth, which curve upwards like sledge-runners (see fig. 460^{2}). In many instances, as, for example, in *Teucrium flavum*, *T. Euganæum*, and *Monarda fistulosa* (see figs. $460^{3, 4, 5, 6, 7, 8, 9}$), there is yet another contrivance for ensuring the proper direction of flight. This consists in the presence of stiff though pliable convergent hairs in the calyx-tube, and their function may be compared to that of the grooves in a rifle. Again, in *Scutellaria* the lobes of the calyx-limb, which is in the form of a tilting helmet with the visor down, determine the path of the seeds after expulsion. The result thus artificially attained by bending down the stalks of the fruiting calyces and letting them fly up again is brought about in nature by gusts of wind, by drops of rain, and most frequently of all by animals brushing against the calyces. In the last-mentioned event one or other of the ejected nutlets may stick to the animal's coat and be carried to a much greater distance than would otherwise be the case. This kind of apparatus rarely occurs in plants other than Labiatæ. The nearest analogy is found in the ejection of seeds from the fruits of several species of the Chickweed genus, *e.g.* *Cerastium macrocarpum* (see p. 448, fig. 340^{4}), where the fruits are curved like the letter **S**, are borne on stiff stalks and hold the ends that open upwards.

One of the most curious forms of mechanism of the catapult variety occurs in the North American *Polygonum Virginicum* (see figs. 460^{10} and 460^{11}). In this plant the fruits are on short stalks, and are arranged in spikes on long switch-like stems. The fruit-stalks are remarkable for the fact that the cells of the cortical parenchyma, which is greatly developed, have their walls strongly lignified, though only slightly thickened. It is also noteworthy that between the stalk and the fruit there is a layer of separation which looks like a joint to the naked eye. The style is transformed into a decurved beak, which is seated upon the fruit, and terminates in two little divergent hooks. When one of these fruits is pushed by a passing animal it is at once detached at the separation-layer and springs away to a distance. The pressure applied to the fruit is apparently transmitted to the short stalk, and gives rise to a condition of tension in the tissue of the stalk analogous to that of a watch-spring. As soon as the pressure ceases the tension relaxes, and the fruit is cast away with great force. For a long time it remained a mystery how these fruits were thrown off in the absence of any animals to give the initial impulse. A few years ago, however, I succeeded in observing the manner in which the long fruiting switches are swayed backwards and forwards by a boisterous wind,

and how they brush against one another and against the branches of neighbouring shrubs as they swing, and thus receive the stimulus necessary to cause them to throw off the fruits. The contact of animals is, however, a more advantageous means of dispersion, inasmuch as the fruits may be left hanging to their coats by the hard styles and the range of distribution be greatly increased thereby. When there is no assistance from animals, and the cast-off fruits simply fall to the ground, the range of projection is not more than 2–3 metres, which is a comparatively small distance from the spot where the fruits were ripened.

The limitation of the range of dispersion is still more marked in the case of fruits which creep or hop along the ground than in those where the action is that of a sling or of a catapult. The fruits in question have stiff and very hygroscopic bristles projecting on one side from their external coats, and these bristles continually change their position according to the varying state of the environment in respect

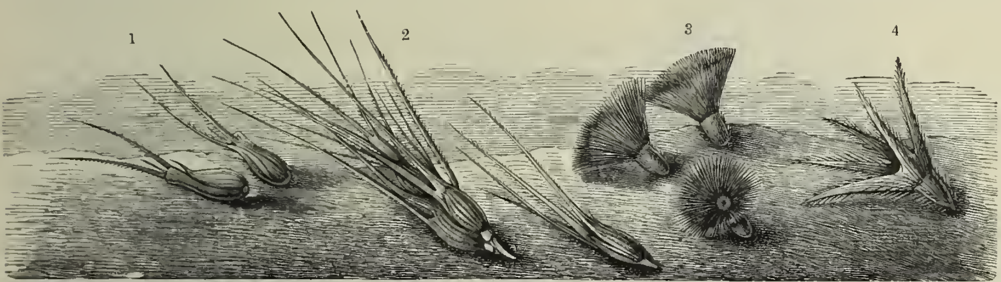


Fig. 461.—Creeping and hopping fruits.

[1] *Ægilops ventricosa.* [2] *Ægilops ovata.* [3] *Crupina vulgaris.* [4] *Trifolium stellatum*

of moisture, and by so doing propel the fruit or seeds, as the case may be, in a definite direction. The awns which project from the glumes of Grasses (e.g. *Elymus crinitus, Secale fragile,* and various species of *Ægilops*; see figs. 461 [1] and 461 [2]), the strong bristles in which the bract-scales of the flowers in Restiaceæ terminate (*e.g.* the South African plant, *Hypodiscus aristatus*), the calyx-bristles and stiff pappus-hairs in Scabiouses and Composites (e.g. *Crupina vulgaris,* see fig. 461 [3]), and the divergent calyx-teeth in Papilionaceæ (e.g. *Trifolium stellatum,* see fig. 461 [4]) constitute structures whereof the different parts alternately approach and recede from one another and so cause a movement resembling that of creeping. In all these cases the hygroscopic structures are furnished with small teeth. Sometimes the teeth are on both sides, sometimes on one side, and sometimes only at the tip (see figs. 462 [1, 2, 3, 4]). The teeth render retrogression impossible, and to that extent determine the direction in which the fruit moves. In *Avena elatior, Avena pratensis,* and several other Grasses the awns which project from the base of the enveloping glumes are bent elbow-wise. The part below the bend is spirally twisted, and as the tissue is extraordinarily hygroscopic, the spiral relaxes or contracts according to the amount of moisture in the air. This spiral motion causes the part of the awn which is above the bend to move like the hand of a watch, but now to one side, now to the other. Of course this movement can only

take place provided the part of the awn which undergoes it is not fixed down anywhere by an obstacle. If one of the lever-arms of the awn encounters a fixed object on the ground the spiral motion of the lower arm sometimes has the effect of forcing the tip of the awn over the obstacle, so that the whole structure shoots obliquely upwards. This phenomenon is especially conspicuous in *Avena sterilis.* In this case two glumes furnished with strong bent awns are to be seen on the fruiting spikelet after it has fallen. An alteration in the environment in respect of moisture causes the two awns to twist in opposite directions, so as to cross one another. After pressing one upon the other, they ultimately slip apart with a sudden jerk, which causes the whole fruit to spring up. This movement is much more like hopping or jumping than creeping.[1]

The distance traversed by creeping, hopping, and bounding fruits is seldom greater than a few decimetres. The movements generally land the fruits almost

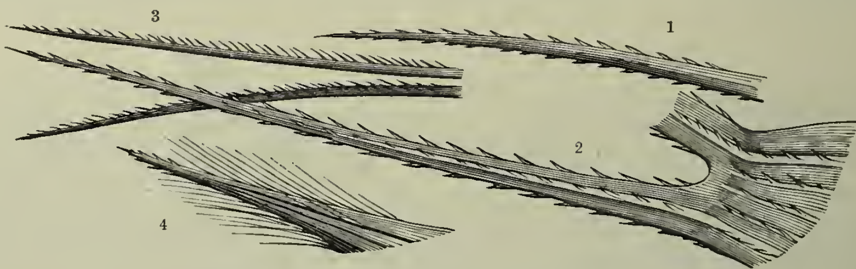


Fig. 462.—Fruits which creep or hop along the ground.

[1] Awn of *Ægilops ventricosa.* [2] Awn of *Ægilops ovata.* [3] Bristles of the pappus of *Crupina vulgaris.* [4] Calyx-tooth of *Trifolium stellatum*; all the figures magnified.

immediately in some *cul de sac*, where they remain, or else the awns gets entangled with the above-ground stems and leaves, and in that case the result of the movements is to imbed the seeds, which are concealed in the fruit-scales, in the earth (see vol. i. p. 617). In such cases no doubt the most important function of the movements in question is to fix the plants in the soil, but on the other hand it cannot be denied that a limited form of dispersion may be and is as a fact achieved by these movements.

The dispersion of fruits through the agency of water takes place in all plants which undergo fertilization under water and detach their fruits when they are quite ripe. To this class of fruits belong the Fungi of the family *Saprolegniaceæ,* and most of those Cryptogams which are known as Algæ. Such facts as have been ascertained by botanists concerning the distribution of the fruits of these plants in the water have been recorded in previous pages (see pp. 49 and 64). This method of dispersion is of less importance in the case of Phanerogams, which are fertilized and ripen their fruits in the medium of the air. At first sight one might

[1] The hopping movements of the fruits of the Mexican plant named *Sebastiana Pavoniana,* and of those of *Tamarix Gallica,* which belongs to the Mediterranean floral area, are not due to alterations in the tension of particular parts of the fruit-coat, but are caused by insect-larvæ which live inside the fruits. In the case of the "Mexican Jumping Bean", the larvæ are those of the small lepidopterous insect named *Carpocapsa saltitans,* and in *Tamarix Gallica* those of the beetle *Nanodes Tamarisci.*

suppose that rain-water running off the plants and then trickling along the ground would be a very effectual means of dispersing fruits and seeds, but closer observation convinces one that distribution is comparatively seldom effected in this manner, and that wherever such dispersion does occur it is invariably supplemented by some other means of dissemination. The best-known instances are afforded by two plants which, on account of their extraordinary properties, were brought to Europe from the East by pilgrims and crusaders in the Middle Ages. They were called "Roses of Jericho", and all sorts of marvellous tales were told concerning them. One of these plants is *Anastatica Hierochuntica,* a Crucifer which grows on the Steppe-lands of Egypt, Arabia, and Syria, and which has the peculiarity that its branches

Fig. 463.—Fruits which open upon being wetted with water.

1 *Anastatica Hierochuntica,* dry. 2 The same when wetted. 3 Fruit of *Mesembryanthemum Candolleanum,* dry. 4 The same when wetted. 5 Fruit of *Mesembryanthemum annuum,* dry. 6 The same after being wetted.

curve inwards when the fruits are ripe in such a manner as to form a trellis round the closed, pear-shaped siliquas, which are very numerous and are situated at the extremities of the ramifications, and to protect them from being touched (see fig. 463 [1]). The shape of the structure in this condition is something like that of an unopened rose, and it remains unaltered so long as it keeps dry. When moistened the branches at once open back and stretch straight out (see fig. 463 [2]). The fruits also open at the same time, and the seeds are then liable to be washed out of the fruit-valves by falling rain. When growing wild *Anastatica* remains closed during the long drought which follows the maturation of the fruits, and it is not till the winter rains set in that the tangle of branches opens and the seeds are washed out of the fruits. The second "Rose of Jericho", *Asteriscus pygmæus,* is a small plant of the Composite family, and ranges from the northern portion of the Sahara to Palestine, being met with in especial abundance in the neighbourhood of Jericho. In this case the branches do not close together when the fruits arrive at maturity, but the involucral leaves, which are arranged in a rosette, close up over the capitula

of fruit and do not open until the winter rains set in and cause the "rose" to unfold, whereupon the fruits are washed away.

Similar phenomena in connection with the rainfall are exhibited by the fruits and seeds of the so-called Ice-plants (*Mesembryanthemum*) which occur in a great variety of forms at the Cape. The capsular fruits of these plants remain closed in dry weather; but the moment they are moistened the valves covering the ventral sutures of the fruit-loculi open back, dehiscence takes place along the ventral sutures, and the seeds, hitherto retained in a double shroud, are washed out of the loculi by the rain (see figs. 463 [3, 4, 5, 6]). Amongst plants belonging to the flora of Europe, the Yellow Stone-crop (*Sedum acre*) responds to the influence of rain in a manner which reminds one strongly of the Ice-plants above referred to. The carpels are arranged radially, and are furnished at the base with wing-like borders, whilst the central part of the external surface of the fruit is in the form of a shallow basin. In dry weather the five fruit-loculi are closed; but the moment a drop of rain falls upon the concave centre they open wide, and the next few drops wash out the seeds, which are of small size, and convey them to the ground. As the rain trickles into the tiniest crevices in rocks and walls, the seeds are carried into holes in vertical or even overhanging cliffs where it would be scarcely possible for them to be deposited by any other means of dispersion. In the case of *Veronica Cymbalaria,* which grows on walls in the south of Europe, the fruits likewise remain closed so long as the weather is dry and only open when they are thoroughly soaked. The seeds are then carried, like those of the Stone-crop, into the holes and crevices of vertical walls by means of the infiltration of rain. Similarly in the cases of *Veronica agrestis* and *Veronica serpyllifolia,* species of Speedwell which grow profusely on cultivated ground, the seeds are washed out of the gaping capsules by rain and conveyed to spots where they find conditions favourable to germination. It is worthy of note that the capsules of *Veronica Anagallis, V. Beccabunga,* and *V. scutellata,* species which grow on banks and in running water, also do not open until they are thoroughly wetted by rain. The explanation of this curious fact must be as follows. If the wind were to act as the means of dispersion there would be a risk of the seeds being deposited on dry places where they would be doomed to perish. On the other hand, the rain carries the seeds on to the wet soil of the marsh or into the shallow water of the brook or pond, as the case may be, where the plant in question finds favourable conditions.

I must again repeat that actual contrivances with a view to seeds being washed out of open fruits by rain are comparatively rare. This, of course, does not exclude the possibility of fruits or seeds unprovided with such contrivances being dispersed by rain, or by the little tributaries of rivulets, which result from showers of rain if once they are transferred by any means into the channels in question. The rills of water which run swiftly down to join larger streams after a violent fall of rain collect not only sand and earth, but also any seeds that may have been deposited on the ground by the wind, and they subsequently set them down with the mud at the edge of the stream. Those fruits and seeds also which fall by chance into running

water, during transportation by aërial currents, may be floated along, and finally deposited by the stream. Numbers of fruits and seeds of the most various kinds of plants are invariably found to have been deposited on the banks of sand by the sides of mountain-torrents, and on the margins of rivers and rivulets after the water has subsided from a state of flood. Many of them, it is true, have no chance of developing, but perish, either because the conditions are unfavourable, or because they have lost their capacity for germination in the transit; others do, however, germinate, and some even thrive luxuriantly. But such seeds can only be said to have been accidentally dispersed by running water, and must not be considered as instances of adaptation to that method of dispersal.

The same statement applies generally to the chance deposition of the fruits or seeds of land-plants in the sea. They may be carried away to a great distance by ocean-currents, may float about for months, and finally be stranded on some remote coast. Experiments have frequently been made with a view to ascertain which fruits and seeds retain their power of germination notwithstanding prolonged immersion in salt water. As a result of these experiments it has been established that the seeds of *Asparagus officinalis, Hibiscus speciosus,* and several other plants do not lose their capacity for germination after immersion in sea-water for a period exceeding a year in duration, a fact which is in itself of great interest. But such results are without significance in relation to the dispersion of fruits and seeds, unless it be also ascertained that the fruits and seeds in question keep afloat upon the surface of the water. For most fruits and seeds sink at once, and sooner or later undergo decomposition at the bottom of the sea. The number of fruits or seeds capable of keeping afloat on the surface for any length of time is extremely small. Of the fruits which are found floating on the sea we may mention first the hard-coated fruits of the group of Palms named Lepidocarynæ. They have a smooth, scaly, completely closed envelope which is impermeable to water, and looks very like a coat-of-mail, and, owing to the fact that this envelope is not in immediate contact with the fruit, but is separated from it by a layer of air, the fruits are able to float on the surface of the water. The large fruit of the Cocoa-nut Palm also is rendered buoyant by a substantial layer of fibres, which incloses a quantity of air, and is itself coated by a layer with fatty contents which prevents the infiltration of water. If fruits of this kind fall into the sea and are cast up by the waves, the seedlings inclosed in them may develop and become denizens of the shores to which they have drifted, provided the conditions, in respect of climate and soil, are such as to permit it. As a matter of fact, fruits cast up by the sea on to remote islands in the Tropics have been known to develop without any human interference.

The phenomena connected with the dispersion of fruits and seeds in still water are altogether peculiar. Currents arising from the slope of the ground do not occur in such water, whilst currents set in motion by the varying temperatures of different layers of water, for the most part, ascend and descend merely, and can occasion very little horizontal displacement of fruits and seeds. The wind is the only agency in

these circumstances that can supply the propelling force necessary to drive such fruits and seeds as can keep afloat from one shore to another. Special mention must be made of three groups of fruits and seeds belonging to this category. These are, firstly, dry fruits which are rendered buoyant by air-inclosing envelopes, as, for instance, in the case of the marsh-plants known as Sedges (*Carex ampullacea, C. vesicaria*, &c.), where the fruit is surrounded by an inflated utricle; secondly, the fruits of Water-Plantains, Flowering-rushes, &c. (*Alisma, Butomus, Sagittaria, Sparganium*, &c.), which are furnished with a thick air-filled cortical parenchyma; and, thirdly, the seeds of some Water-lilies. In the case of the white Water-lilies

464.—Dispersion of fruits and seeds by the wind.

1 *Anthyllis Vulneraria*; two fruiting calyces are falling from the plant. 2 Longitudinal section through a fruiting calyx belonging to the same plant; the pod is visible in the interior. 3 *Trifolium tomentosum*; one head of inflated fruiting calyces is detached, and another is still attached to the stalk. 4 Longitudinal section through a fruiting calyx belonging to the same. 5 *Medicago scutellata*. 6 *Ostrya carpinifolia*; branch with two fruit-spikes. 7 Longitudinal section through the saccate cupule which envelops the nut in this plant

(*Nymphæa*), each seed is enveloped in a coat (*arillus*), which loosely clothes the outer integument (*testa*) of the seed, so as to leave a layer of air between the two. In the species of the genus *Nuphar* there is no arillus, but the carpels separate when the fruit is ripe into two layers, of which the outer one is green and succulent, whilst the inner one is white and charged with air, and incloses a large number of seeds. In all these cases the seeds are enabled to float by their envelopes, and are driven along on the surface of the water by the wind.

In a similar manner the wind causes certain detached as well as aggregated fruits to roll along upon level ground. This phenomenon is observed particularly in regions where a long period of drought follows the short summer season of development; and accordingly the plants concerned are especially abundant in the vicinity of the Mediterranean Sea and in Steppe-lands. Several Umbellifers indigenous to the high

Steppes of the East produce smooth, ellipsoidal fruits about the size of a hazel-nut and so light that if one of them is laid on a person's open hand when his eyes are shut he does not perceive its presence. The extraordinarily small weight of these fruits is due to the fact that their structure includes a layer resembling the pith of the Elder. A fruit of *Cachrys alpina* measures 13 mm. in length and 10 mm. in thickness and weighs 0·07 grm.; another *Cachrys* fruit from Shiraz is 15 mm. long and 10 mm. thick and weighs only 0·06 grm. When fruits of this kind fall they are rolled along over the Steppe by the wind and only come to rest when they are caught in some crack in the parched clay soil or get lodged in a hole in a rock. A few Papilionaceæ also produce rolling fruits of the kind. One of the groups of species belonging to the Medick genus, of which *Medicago scutellata* (see fig. 464 [5]) may be taken as a type, has pods which are spirally curled into round balls and which, when their seeds are ripe, detach themselves from their stalks and are rolled

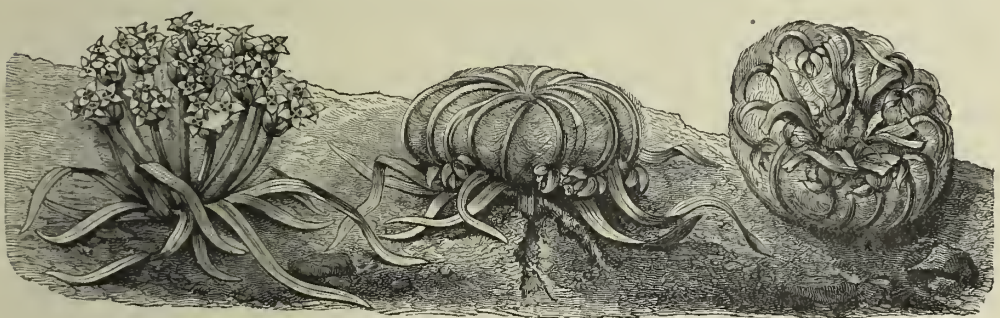


Fig. 465.—Dispersion of fruits and seeds by the wind. *Plantago Cretica.*

a little way along the ground every time there comes a gust of wind. The same thing happens in the case of *Blumenbachia Hieronymi*, a native of South America, belonging to the family Loasaceæ. Although the spherical fruit of this plant has a diameter of 2·5 cm. it only weighs 0·34 grm. when thoroughly dried. As soon as the seeds are ripe the fruit-stalk withers and the round fruits, which are then left lying loose upon the ground, are rolled away by the gentlest breeze. If their career is stopped anywhere, and they get wetted by rain, the openings which are already formed in them become enlarged and a quantity of wrinkled seeds fall out. *Paronychia Kapella* (see fig. 468 [6]), a plant of wide distribution in the floral area of the Black Sea, where it grows on dry rocky soil, brings small fruits to maturity in the height of summer, each of which is surrounded by silvery white membranous bracts. When the season for the dispersion of these fruits arrives the entire tuft of fruits, which is in the form of a spherical glomerule, becomes detached from the branch on which it grows and lies lightly on the ground, where the least puff of wind imparts to it a swift rolling motion. Sometimes if the ground is uneven the rolling is converted into a hopping and springing motion, and occasionally such masses of fruit are raised by powerful gusts of wind and carried considerable distances through the air. In several species of Clover, such as *Trifolium globosum*, *T. subterraneum*, and *T. nidificum* (see fig. 468 [10]) there are only a few perfectly

developed flowers in the cluster growing at the end of the flower-stalk, whilst a number of abortive flowers are crowded together in a tuft in the middle of the inflorescence. At the season when the legumes are formed from the fertile flowers the calyx-teeth of the abortive flowers increase in size and assume the shape of long hairy bristles, which bend over outwards and form a loose globular inclosure round the head of leguminous fruits. These balls afterwards become detached from the stalk and are rolled away by the wind.

Even entire plants are in some cases uprooted or have their stems severed from the roots at the base in the fruiting season, and are then rolled along like balls by the wind. The most remarkable instance is that of *Plantago Cretica*, which is shown in fig. 465. This is an annual plant possessing an abbreviated main axis from which springs a tuft of stiff, erect flowering stems. When the fruits begin to ripen the stems curve down in coils to the periphery of the plant, and by so doing give a strong pull to the abbreviated axis and to the simple tap-root, which is inserted in the earth in a vertical position. The soil on which *Plantago Cretica* grows being completely dried up in summer is full of cracks, and the pull imparted in the manner described is in consequence sufficient to uproot the plant. The plants now in the fruiting stage have the form of flattened balls and are very light, so that the entire structure is rolled along by gusts of wind. *Plantago Cretica* is also a type of the so-called "Steppe-witches" and "wind-witches", which are a source of so much wonder to travellers in the regions of Steppes. On the high table-land of Persia there is a plant named *Gundelia Tournefortii* which grows in loose, round, prickly sods, and has a tap-root deeply sunk in the earth. When the fruits are ripe the neck of the root rots away and the round sod then rests simply with its stiff lower branches in contact with the ground. Whenever the slightest wind begins to blow innumerable quantities of these sods are set in motion, and are thus dispersed over the plateau. The herbaceous plants of the Steppes of Southern Russia which exhibit the phenomenon of a decay of the bases of the stems in the fruiting season and a consequent liberation of the dry aërial portion of the plant belong to families of the most various kinds. The most common are *Alhagi camelorum*, *Centaurea diffusa*, *Phlomis herba-venti*, *Rapistrum perenne*, and *Salsola Kali*. It often happens that a number of these dry, branching herbs get hooked and entangled together as they roll along, until at length they form a ball as big as a cartload of hay. Such balls have also been seen lifted up by whirlwinds and driven bounding over the plain. It is not surprising that this marvellous phenomenon has appealed to the imagination of the inhabitants of the Steppes, and has even become a subject for witch-lore whence have arisen the names Wind-witch and Steppe-witch.

It only happens in a small proportion of these cases of rolling fruits, wind-witches, and the like, that the seeds are strewn out as they are bowled along; when this does occur it is usually occasioned by some unevenness in the ground which gives a sudden jog to the rolling body. In the majority of cases the seeds do not escape until the fruits are brought to rest by encountering some insurmountable obstacle, the reason being that the seed-vessels only open when they become wet.

This brings us back to the fruits of *Mesembryanthemum* and *Anastatica*, which were described on pp. 845, 846. Sometimes these also play the part of rolling fruits. The capsules of *Mesembrianthemum* detach themselves from their stalks, the plants of *Anastatica* become partially uprooted, and lie during the dry season of the year loose upon the earth. A puff of wind blows them into hollows in the ground or cracks in rocks, where they are held prisoners. The seed-cases, however, still remain closed. At last the winter rains set in, whereupon the capsules open, the seeds are washed out, and after a short time they germinate on the saturated ground, to which the rain has conveyed them.

Innumerable are the cases of wind-dispersed fruits and seeds which remain floating in the air for a period of more or less duration after severance from the mother-plant, and which have their fall retarded by special contrivances for the purpose. The conformation of fruits and seeds of this category must be such that the air offers great resistance to their fall, and it is important that they should possess as small a weight as possible in relation to their size. It is well known that the spores of Fungi often remain for a long time floating in the air as constituent particles of the dust. Some seeds, too, are so extraordinarily light that they also look simply like dust and are able to remain for a comparatively long period suspended in the air. Amongst such dust-like seeds those of Orchids must be mentioned first. A single seed of *Goodyera repens*, for instance, weighs only 0·000002 grm. Several other plants, particularly parasites and saprophytes which live in deep beds of humus, possess extremely light seeds, as is shown by the annexed table:—

Name of Plant.	Weight of Seed in grams.	Name of Plant.	Weight of Seed in grams.
Stanhopea oculata	0·000003	*Sempervivum acuminatum*	0·00002
Monotropa glabra	0·000003	*Parnassia palustris*	0·00003
Pyrola uniflora	0·000004	*Sedum maximum*	0·00004
Umbilicus erectus	0·000006	*Lepigonum marginatum*	0·00007
Gymnadenia conopsea	0·000008	*Spiræa Aruncus*	0·00008
Orobanche ionantha	0·00001	*Veronica aphylla*	0·0001

To enable these seeds to float in the air for as long a time as possible they are more or less flattened, and their centre of gravity is so placed that they always present the broad side to the direction of descent. The same form of adaptation occurs in seeds which are shaped like leaflets, scales, or delicate discs. A compressed seed is usually surrounded by an attenuated margin, a membranous border, or a radiating fringe of extremely fine processes, as in *Funkia, Lilium, Tulipa, Fritillaria, Rhinanthus, Veronica, Lepigonum, Cinchona, Bignonia, Dioscorea,* and *Heliosperma* (see p. 423, figs. 318 [4, 5, 7], and figs. 466 [2, 4, 5]). In some cases the entire pericarp is modified in this manner, as in *Hymenocarpus, Mattia, Peltaria, Ptelea,* and *Ulmus* (see fig. 467 [4], and p. 143, fig. 232 [2]). Amongst Umbelliferæ, Mimoseæ, Papilionaceæ, and Cruciferæ cases also occur in which the mericarps, the segments of siliculas and lomenta, or the seed-studded valves of ordinary pods and siliquas,

according to the particular plant considered, are in the form of scales and leaflets which become detached separately. Instances of this kind are afforded by *Artedia squamata, Megacarpœa laciniata, Mimosa hispidula, Æschynomene glabrata,* and *Lunaria rediviva* (see figs. 467 [1, 5, 11], and p. 445, fig. 339 [1], and fig. 466 [1]).

With these forms may be classed also such fruits and seeds as are furnished with wing-shaped appendages. The wings are either produced from the seed-coat, as in Pines and Firs (see p. 441, fig. 335 [5]), or else arise from the carpels. A single wing, which stands out to one side, is developed in the case of the pods of some tropical Leguminosæ (e.g. *Securida virgata* and *Centrolobium robustum*; see p. 445, fig. 339 [5]), and in the separate parts of the double fruit of the Maple and of the

Fig. 466.—Dispersion of fruits and seeds by the wind.

[1] Siliquose fruit of *Lunaria rediviva*; the two valves of the fruit have become detached; seeds are fastened to the inside of each valve. [2] Opened capsule of a *Bignonia* from which winged seeds are being carried off by the wind. [3] Capsule of *Heliosperma quadrifidum* after dehiscence; the seeds are being shaken out by the wind. [4] A seed of *Heliosperma quadrifidum* magnified. [5] Capsule of a *Dioscorea* after dehiscence, the winged seeds being blown away by the wind.

Banisterias, belonging to the Malpighiaceæ (e.g. *Acer Monspessulanum* and *Banisteria Sinemariensis*; see figs. 467 [7] and 467 [10]). The achenes of Birches and of the Tree of Heaven (e.g. *Betula verrucosa* and *Ailanthus glandulosa*; see figs. 467 [2] and 467 [12]) bear two laterally placed wings in each case. The mericarps of many Umbelliferæ (e.g. *Opoponax Cretica* and *Laserpitium latifolium*; see figs. 467 [6] and 467 [13]) have wings projecting from the back; the fruits of some Polygonums (e.g. *Polygonum dumetorum* and *P. Sieboldi*; see fig. 467 [3]) are furnished with three wings, and those of *Triopteris bifurca,* one of the Malpighiaceæ, with four wings, of which two are large and two small (fig. 467 [9]). In other cases some of the floral-leaves are transformed into wings for the fruit, as, for instance, in *Dryobalanops,* of the family Dipterocarpeæ, in which five sepals are in the form of long wings (see fig. 468 [5]), and in *Gyrocarpus,* of the family Combretaceæ, in which two of the 4–7 unequal segments of the calyx are similarly adapted (see fig. 467 [8]). It is of common occurrence for the fruits to become winged

in consequence of the continuous growth after the flower has faded and the ultimate desiccation of persistent bracts, as is seen in the Hop (*Humulus Lupulus*), the

Fig. 467.—Dispersion of fruits and seeds by the wind.

1 *Megacarpœa laciniata.* 2 *Ailanthus glandulosa.* 3 *Polygonum Sieboldi.* 4 *Ptelea trifoliata.* 5 *Æschynomene glabrata.* 6 *Opoponax Cretica.* 7 *Banisteria Sinemariensis.* 8 *Gyrocarpus Asiaticus.* 9 *Triopteris bifurca.* 10 *Acer Monspessulanum.* 11 *Artedia squamata.* 12 *Betula verrucosa.* 13 *Laserpitium latifolium.*

Oriental Hornbeam (*Carpinus Orientalis*), and the Lime (*Tilia intermedia*) (see figs. 468 [1] and 468 [2]). In many cases, as, for instance, in the Tree of Heaven (*Ailan-*

thus), the two wings exhibit a slight spiral twist resembling a propeller; this occasions a peculiar gyratory motion of the fruit as it sails along in the air. Wherever there is only a single wing which projects from one side, the centre of gravity has an eccentric position, and the fruits and seeds of this class spin quickly

Fig. 468.—Dispersion of fruits and seeds by the wind.

1 *Carpinus Orientalis.* 2 *Tilia intermedia.* 3 *Armeria alpina.* 4 *Melica altissima.* 5 *Dryobalanops.* 6 *Paronychia Kapella.* 7 *Briza maxima.* 8 *Scabiosa graminifolia.* 9 *Humulus Lupulus.* 10 *Trifolium nidificum.*

as they fall freely through the air. The motion in question is particularly well marked in the half-fruits of the Sycamore and the seeds of Pines.

The same object as is attained in the above cases by the development of alate processes is brought about in other plants by the transformation of dry bracts or floral-leaves into light, loose, saccate, or inflated envelopes round the fruits or seeds.

When quite dry, these envelopes are extremely thin and delicate, and sometimes their weight is still further reduced by a portion of the tissue being torn during desiccation, in which case the whole assumes a sieve-like or latticed appearance. The small fruit within the envelope defines the position of the centre of gravity, and consequently determines also the attitude of the structure as a whole that best adapts it to dispersion by the wind. In several Papilionaceæ, as in *Callipeltis cucullata* and the yellow-flowered species of Clover (e.g. *Trifolium agrarium* and *T. badium*; see figs. 469 [1, 2, 3, 4, 5]), the dried petals of the corolla are fashioned into an envelope which incloses the small 1-seeded legume, and in several species of Lady's Fingers (e.g. *Anthyllis tetraphylla* and *A. Vulneraria*; see figs. 464 [1]

Fig. 469.—Dispersion of fruits and seeds by the wind.

Trifolium badium. — [1] Inflorescence. [2] Same with fruit ripened. [3] Flower. [4] Fruit enveloped in the dried petals. [5] Longitudinal section through the fruit in its envelope of petals.—*Verticordia oculata.* [6] Fruit. [7] Longitudinal section through the fruit. [8] Five "feathers" from the fruit. [3], [4], [5], and [8] magnified.

and 464 [2]), and some species of Clover of the tribe *Vesicastrum* (e.g. *Trifolium fragiferum* and *T. tomentosum*; see figs. 464 [3] and 464 [4]), the inflated calyx plays the same part. In many Labiates also (e.g. *Calaminta, Salvia, Thymus*), the calyx is converted into a dry, saccate envelope, which is severed from its stalk by any external stimulus, and then serves as a means of dispersing the ripe nutlets contained in it. In the Hop-hornbeam (*Ostrya*, see figs. 464 [6] and 464 [7]), the small nut is enveloped in the sac-like bract; and in many Grasses, as, for instance, *Briza maxima* and *Melica altissima* (see figs. 468 [4] and 468 [7]), the dry glumes constitute a covering to the small fruit which adapts it to dispersion by the wind.

One of the commonest devices for keeping fruits and seeds suspended in the air is of the nature of a parachute. This form of mechanism occurs in the shape either of tufts of hairs or of membranous borders. In Willow-herbs (*Epilobium*; see fig. 472 [6]), Asclepiadaceæ (e.g. *Cynanchum*, see fig. 471 [6]), and several Bromeliaceæ

(e.g. *Tillandsia*; see fig. 475 [2]) only one pole of the seed is furnished with a tuft of hairs, whilst in *Adenium* (see fig. 471 [2]), belonging to the family Apocynaceæ, both poles are so provided. In Valerianaceæ (e.g. *Valeriana*; see fig. 471 [3]) and in Compositæ (e.g. *Senecio* and *Taraxacum*; see figs. 471 [1, 8, 9]) the tuft of hairs which acts as a parachute springs from the upper extremity of the achene. Sometimes the parachute and the body it keeps in suspension are connected by a slender stalk (e.g. in *Tillandsia* and *Taraxacum*); but usually the former is directly sessile on one extremity of the seed or indehiscent fruit as the case may be. In *Verticordia* (see figs. 469 [6, 7, 8]), of the family Myrtaceæ, a strange and beautiful parachute is formed by five petals which are in the form of little fans, each composed of ten

Fig. 470.—Dispersion of fruits and seeds by the wind.

Bombax. [2] *Anemone sylvestris.* [3] *Gossypium Barbadense.*

feather-like lobes, and in some Labiatæ, as, for instance, *Micromeria nervosa* (see fig. 471 [7]), the radiating, hair-studded segments of the fruiting calyx constitute a similar apparatus. On the other hand, in several other Labiatæ (e.g. *Ballota acetabulosa*), in many Plumbaginaceæ (e.g. *Armeria*; see fig. 468 [3]), and in several Dipsaceæ (e.g. *Scabiosa*; see fig. 468 [8]) the parachute is developed from the delicate, dry membranous calyx or from the epicalyx. Nor must reference to the Cape Silver Tree (*Leucadendron argenteum*, one of the Proteaceæ) be omitted. The fruits here are produced in large cones not unlike those of the Stone Pine (*Pinus Pinea*) in form and dimensions. Each bract of the ripe cone subtends a fruit consisting of a nut with persistent wiry style and stigma. The 4-lobed perianth also persists as a membranous parachute, its originally free apices having become connate above the nut and around the style. Ultimately the original attachment of the perianth below the ovary becomes dissolved, and as the nut falls out of the cone

the style (with nut suspended below) slides out of the hole, around which the perianth-lobes are connate, until its further progress is arrested by the button-like

Fig. 471.—Dispersion of fruits and seeds by the wind.

1 *Senecio vulgaris.* 2 *Adenium Honghel.* 3 *Valeriana tripteris.* 4 *Typha Schuttleworthii.* 5 *Eriophorum angustifolium.* 6 *Cynanchum fuscatum.* 7 *Micromeria nervosa.* 8 and 9 *Taraxacum officinale.* 10 *Salix Myrsinites.*

stigma. The perianth here forms a beautiful parachute, with the nut hanging freely below at the end of a string, like an enterprising balloon-gymnast.

From the fruits and seeds equipped with parachutes we pass to those which are embedded in masses of wool or in envelopes of silky hairs, and are thereby enabled

to remain poised in the air. The hairs arise either from the surface of the seed-coat (*testa*), as in the Cotton trees (*Bombax* and *Gossypium*; see figs. 470 [1] and 470 [3]), or else they spring from the base of the seed, as in Poplars and Willows (*Populus* and *Salix*; see p. 423, figs. 318 [3] and 318 [4]; p. 424, fig. 319 and fig. 471 [10]). In the Bulrush (*Typha*; see fig. 471 [4]) they take their rise from the pedicels of the fruits, and in several Ranunculaceæ (e.g. *Anemone sylvestris*; see fig. 470 [2]) from the achenes themselves. In other cases they arise from the floral-leaves, as, for instance, in the Cotton-grass (*Eriophorum*; see fig. 471 [5]), where the structure which repre-

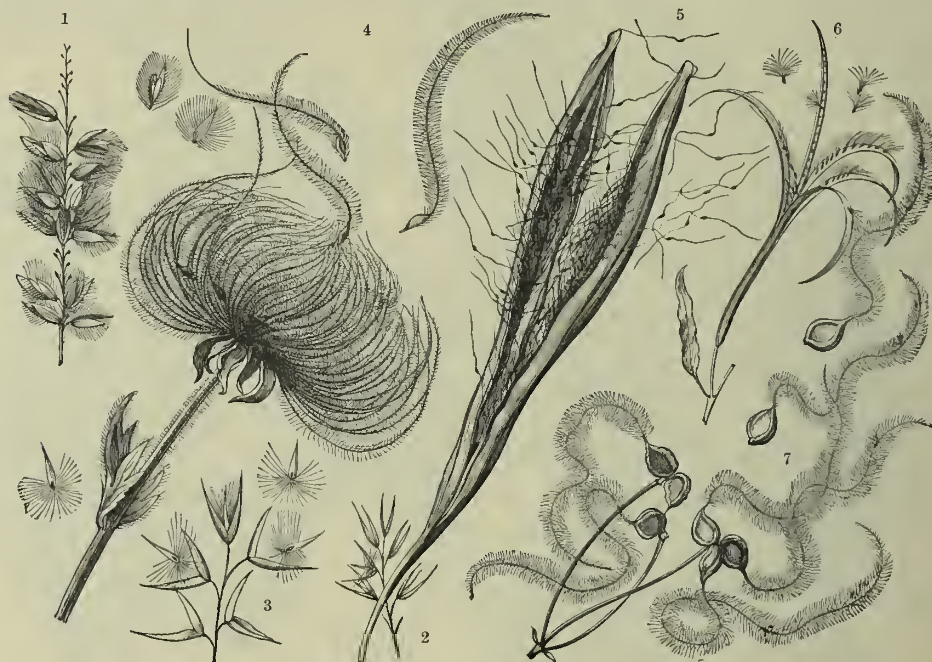


Fig. 472.—Dispersion of fruits and seeds by the wind.

[1] *Melica Balansæ.* [2] *Calamagrostis Epigeios*; nat. size. [3] The same magnified. [4] *Geum montanum.* [5] *Æschynanthus speciosus.* [6] *Epilobium collinum.* [7] *Clematis Flammula.*

sents the perianth is transformed into delicate hairs, and in *Trifolium plumosum*, where the fruiting calyx is wrapped in wool. In many Grasses the glumes are beset with extremely fine hairs (e.g. *Melica* and *Calamagrostis*; see figs. 472 [1, 2, 3]), in *Micropus*, of the Compositæ, long hairs project from the scales of the involucre and envelop the entire capitulum in a flocculent mass, and in the Venetian Sumach or Wig-plant (*Rhus Cotinus*) the stalks of abortive flowers are covered with a woolly down, which serves for the dispersion of the fruits, whose stalks are usually free from wool. Lastly, we have the cases where the fruits or seeds are kept suspended in the air for a more or less prolonged period by means of special hairy tails. Either the seeds are tailed at both ends, as in *Æschynanthus* (see fig. 472 [5]), one of the Gesneraceæ, in which the tiny seeds are furnished with two long hairs, one at each end, or else the style lengthens after the flower has faded and becomes converted into a spirally-curved tail, which remains attached to one side of the

achene, and acts like a parachute, as may be seen in *Geum*, *Atragene*, *Pulsatilla*, and *Clematis* (see figs. 472 [4] and 472 [7]). In some Grasses, such as *Stipa* (see vol. i. p. 619, fig. 147 [1]), an awn is developed in the form of a long feather, which soars above the tightly-closed glumes inclosing the fruit.

Several of the fruits and seeds above described are directly exposed to the wind. Owing to the fact that the desiccation of the envelopes and stalks of the fruits at the time of ripening of the seeds renders certain layers of tissue brittle, a moderate wind is sufficient to cause the fall of such fruits, and the same gust that brings about their severance from the plant drives the fruit along in a horizontal direction. The fruit does not fall to the ground until the wind drops, or until its progress is arrested by some obstacle.

Many other fruits and seeds detach themselves spontaneously from the mother-plant when they are ripe, but are not directly exposed in consequence to the full shock of the wind. In these we find many contrivances for the purpose of ensuring that the parts to be dispersed shall be brought out from their shelter, and given over to the wind at the proper time. In some tropical Orchids which are epiphytic on the bark of old trees (viz. *Aerides*, *Angræcum*, *Sarcanthus*, *Saccolabium*, &c.), the capsular fruits contain, in addition to the small seeds, hair-like cells, with spirally-marked and obliquely-pitted walls (see fig. 473). *Vanda teres* (see fig. 475 [1]) may be taken as a type of this group. The hair-like cells in question are woven together into a sort of felt. They are extremely hygroscopic, and twist and turn about in a curious manner if the slightest change of condition in respect of moisture occurs.

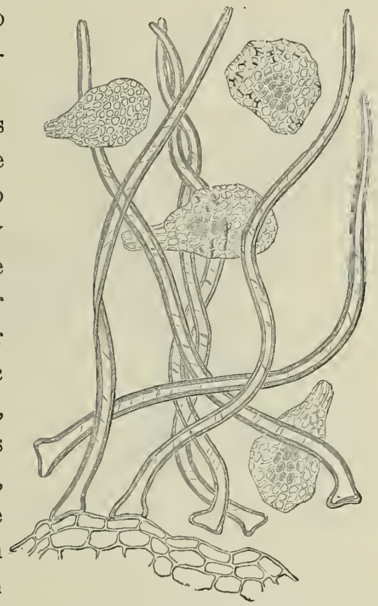


Fig. 473.—Seeds of the Orchid *Vanda teres*, which are moved from the interior to the surface of the capsule by hygroscopic hair-like cells, and are thus exposed to the wind; ×100.

When the valves of the capsules move apart under the influence of a dry wind, an active movement is simultaneously initiated in the matted hairs. The felt becomes to a certain extent puffed up, and consequently it squeezes out between the valves of the capsule, and drags the seeds, which are imbedded amongst the hairs, from the interior to the surface of the capsule, where they are liable to be blown away by the least breath of wind. This happens, as was said, when a dry wind is blowing. In wet weather the capsules close up, and conceal both hairs and seed once more in their interior. Similar phenomena may be observed in the fruit-capitula of some Composites whose fruits are spontaneously detached from the receptacle on ripening. In damp weather the loose achenes lie hidden in the involucral cup, as though at the bottom of a basket, and the hairy pappuses appended to the achenes are clubbed together. When the atmosphere is dry, the involucre, which is composed of hygroscopic scales, opens, and the pappuses of the fruits within spring apart, and so act as

levers. The fruits are speedily raised by this means above the edge of the open involucre to a sufficient height to expose them to the wind. In some other Composites, such as the Dandelion (*Taraxacum*), the fruits do not detach themselves spontaneously from the floral receptable when they are ripe. The segments of the involucre close together in wet weather, as do likewise the hairs or plumes of the pappus. In dry weather the involucre opens, whilst the feathers of the pappus diverge so as to assume the form of a parachute, and in that condition offer a comparatively large surface for the wind to act upon. A moderate gust of wind is now able to lift the fruits, with their expanded parachutes, off the receptacle and carry them away (see fig. 471 [9]). If no breath of wind stirs, they remain upon the receptacle; the damp atmosphere of evening causes both parachutes and involucre

Fig. 474.—Dispersion of fruits and seeds by the wind. Fruits of a Thistle (*Cirsium nemorale*) floating in the air and becoming detached from their parachutes and dropping to the ground whenever they encounter an obstacle in the course of their flight.

to close up again, and the process of dispersion is suspended until next day, when the air is dry once more and the sun shining. In *Andropogon Ischæmum, Avena pratensis,* and many other Grasses, the flowering glume has an awn composed of spirally-marked and highly hygroscopic cells, and bent like an elbow, and this awn undergoes a marked spiral torsion, accompanied by a slight downward flexure whenever the air is dry. The distal arm of the awn is liable to get pressed against objects in the course of these movements, and it then acts as a lever in raising the fruits above the outer glumes. They are then easily blown away by a puff of dry wind. In several Scabiouses, also, the breaking up of the fruit-capitulum, and the raising of the fruits with a view to their dispersion by the wind, are occasioned by a bristling movement on the part of the hygroscopic setæ of the calyx. Each fruitlet in the Valerian is surmounted by a pappus of delicate feathery hairs. When the air is damp these feathers are folded together; when it is dry they become unfurled (see fig. 471 [3]). In this condition of divergence, they present an ample surface to the wind, and the slightest gust detaches the fruits and blows them away. A similar phenomenon occurs in *Dryas,* and in some other plants; but we cannot now enter into the details of these cases.

In the case of Willow-herbs (*Epilobium*) and of some Pines (*Pinus nigricans*, *P. sylvestris*, &c.) the fruit-valves and fruit-scales which cover the seeds only open back under the influence of the sun's warmth, and when a dry wind is blowing, and the same wind which thus operates on the valves and scales also carries off the seeds the moment they are exposed, they being furnished with wings or tufts of hair with a view to aërial dispersion. The reader must be referred to p. 447 for a description of the manifold effects of a dry wind on the fruits and seeds in question. First, the dry capsules open; secondly, the seeds, hitherto lying in the interior of the fruits, where they are protected against moisture, are shaken out by the swaying to and fro of the elastic fruit-stalks; and thirdly, these seeds are caught up and scattered by the wind.

The distance to which fruits and seeds which are adapted to aërial transit by means of wings, hairy tails, parachutes, inflated envelopes or woolly coverings, as the case may be, are conveyed by the wind depends on the degree of perfection of their mechanism, on the condition of the air in respect of moisture, and on the strength of the current of air by which they are transported. When the weather is calm and sunny, innumerable of the lighter fruits and seeds are carried up to a great height by the ascending currents which are generated in the atmosphere; but they usually descend again after sunset at a little distance from the spot where they were taken up. Such excursions do not conduce so much to a dispersion of plants over large areas as to their deposition on shelves and in crevices of steep walls of rock, where seeds would not otherwise easily acquire a footing. Currents moving in a horizontal direction may, it is true, convey their freight of fruits and seeds over extensive tracts of country, but very exaggerated notions are usually entertained concerning the distances thus attained. Amongst the numerous species of fruits and seeds blown by storms of wind to the tops of the Alps and left upon the snowfields above the glaciers, not a single one derived from distant parts (*i.e.* from another district) has been found after careful examination of the deposited matter; and from this we may infer that, even on mountains, fruits and seeds are scarcely conveyed any further by a raging wind than when they are blown from one side of a valley to the other.

In many plants the wings or parachutes, as the case may be, only remain attached to the seeds or fruits for the period of their journey through the air. If the winged seed of a Pine gets stranded anywhere the membranous wing drops off, and the seed is then no longer capable of flight. This phenomenon is even more marked in the fruits of Thistles (e.g. *Carduus* and *Cirsium*; see fig. 474). The achenes, which are comparatively large, are supported by parachutes and float quietly in the air, but the moment one of them strikes against any obstacle the fruit severs itself from the parachute and falls to the ground. There can be little doubt that to this mode of dispersion must be attributed the common occurrence of Thistles at the foot of walls and in hedgerows, inasmuch as the floating fruits are carried against such structures with especial frequency. In other cases the fruit or seed maintains permanently a firm connection with the parachute, and the latter

serves to fasten it to some place where the conditions requisite for germination are present. For instance, when the seeds of *Tillandsia* (see 475 [2]) come into contact with the boughs of old trees, as they are blown along in a horizontal direction, they fasten on to the bark where they are able to germinate immediately. Thus the pappus to which the seed owes its buoyancy serves subsequently to anchor it to a substratum favourable to its development.

The modes of dispersion of fruits and seeds through the agency of animals are

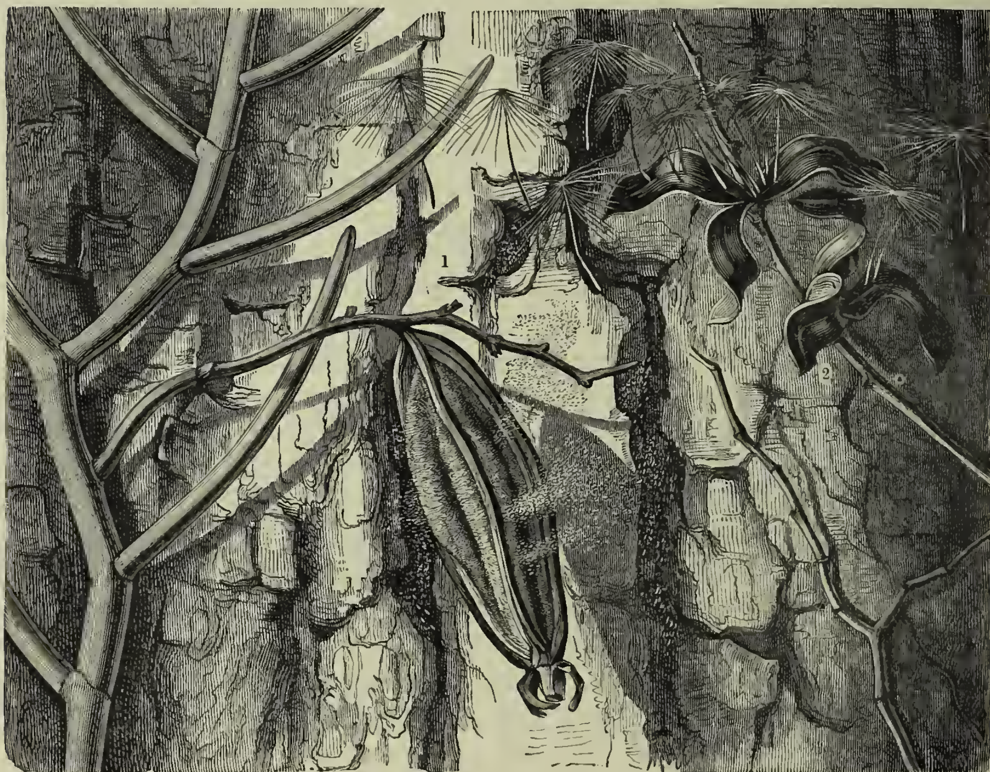


Fig. 475.—Dispersion of fruits and seeds by the wind.

[1] Capsule of *Vanda teres*, from which the seeds have been transferred to the air by means of hygroscopic hairs, and are being blown away. [2] Open capsule of a *Tillandsia*; the seeds are being lifted out by the wind by means of their parachutes. If a seed is blown against the bark of a tree it is anchored there by the hairs of the parachute.

almost as varied as the different methods of dissemination by the wind. In many cases such dispersion is brought about by the animals using the fruits and seeds in question for food; the undigested parts are excreted, and any embryos which may have survived the passage through the alimentary canal subsequently germinate. As the fact of this mode of dispersion has been a matter of dispute amongst botanists, and could only be established by experiment, I determined to feed various animals with selected fruits and seeds, and to ascertain first of all whether the embryos preserve their vitality after passing through an animal's intestinal canal. Fruits and seeds belonging to 250 different species of plants were used for the purpose, and

the following birds were fed with them: blackbird, song-thrush, rock-thrush, robin, jackdaw, raven, nutcracker, siskin, goldfinch, serin-finch, titmouse, bullfinch, cross-bill, pigeon, fowl, turkey, and duck; and also the following mammals: marmot, horse, ox, and pig. After each meal the fæces were examined, to ascertain what seeds they contained, and were then laid on a separate bed of earth, and at the same time fruits and seeds of the same plants which had not been used for food were planted in an adjoining bed. It would be out of place to set forth here all the precautions which it was necessary to take in conducting these laborious researches, and I shall confine myself to a statement of the most important results obtained from 520 separate experiments.

As regards the mammals subjected to experiment very few words will suffice. Almost all the fruits and seeds administered to them, whether they took them voluntarily or unawares mixed with their ordinary food, were destroyed either at once or upon being chewed with the cud. It is true that a few millet-seeds germinated from the ox-dung, and must therefore have escaped being crushed during rumination, and that one or two solitary specimens of lentil-seeds and oat-fruits similarly passed uninjured through a horse, whilst *Cornus alba, Hippophae rhamnoides, Ligustrum vulgare, Malva crispa, Rhaphanus sativus,* and *Robinia Pseudacacia* all germinated after passing through a pig; but the number of the seedlings so obtained was scarcely appreciable as compared with the number of fertile seeds swallowed in the animals' food, and the fruits and seeds of about 60 other species of plants completely lost all power of germination during their passage through the intestines. The birds resolve themselves into three groups in relation to the matter in question. The first group includes those which grind up even the hardest fruits and seeds in their muscular and hard-coated "gastric mills" which are in addition usually filled with small stones and sand. Amongst these, some strip the fruits and seeds when they first lay hold of them, and thereby condemn them to destruction. To this group the following birds of those employed in the experiments belong, viz. the turkey, the hen, the pigeon, the cross-bill, the bullfinch, the goldfinch, the siskin, the serin-finch, the nutcracker, the titmouse, and the duck. No seed capable of germination was found under ordinary conditions in the excrements of these birds; only when on a few occasions food was forcibly administered to the hen and to ducks, so that their crops must have been overloaded, were a few seeds found to have escaped pulverization, and to still possess the power of development. The seeds in question belonged to *Arenaria serpyllifolia, Papaver Rhœas, Sisymbrium Sophia, Ribes rubrum, Ligustrum vulgare, Fragaria Indica,* and other species. Ravens and jackdaws form a second group, in that the stones of the drupes and hard-coated seeds of the berries which they ate passed uninjured through the intestine, whilst soft-coated seeds and fruits were all destroyed. It is worth mentioning in particular that after these birds had been fed with cherries their excrements contained cherry-stones 15 mm. in diamater, every one of which was able to germinate. Of the birds selected for experiment, the blackbird, the song-thrush, the rock-thrush, and the robin belonged to a third group. Of these the

blackbird was the least fastidious about its food. It even swallowed the fruits of the Yew without afterwards relieving its crop of the stony seeds, and it never rejected a single fruit that was mixed with its food. The song-thrush refused all dry fruits of 5 mm. diamater or more, even when they were mixed with the finely-chopped meat with which the bird was fed. They also avoided certain strong-smelling fruits, such as that of the Yarrow. On the other hand, the aromatic fruits of Umbelliferæ (e.g. *Bupleurum rotundifolium* and *Carum Carvi*) were eaten with great avidity. The seeds of the Tobacco-plant, Henbane, and Foxglove mixed with the food were not rejected and caused no ill effects, and no more did the berries of the Deadly Nightshade, which were devoured greedily. On the other hand, a song-thrush sickened after eating berries of *Phytolacca*. When fleshy fruits with seeds of diameter exceeding 5 mm., such as those of *Berberis, Ligustrum, Opuntia,* and *Viburnum* were introduced into the crop, the pulp passed thence into the gizzard, but all the seeds were thrown up. Many seeds, as, for example, those of *Lychnis flos-Jovis,* were carefully removed from the rest of the food with which they had been mixed. The seeds of fleshy fruits which were greedily devoured were thrown out of the crop if the stones which they inclosed measured as much as 3 mm. The interval of time between ingestion and evacuation was surprisingly short in the birds of the third group. A thrush fed with *Ribes petræum* at 8 o'clock in the morning excreted numbers of the seeds after the lapse of three quarters of an hour, and seeds of *Sambucus nigra* were found to have passed through the alimentary canal in half an hour. The majority of seeds took from 1½ to 3 hours to perform the journey. Curiously enough, the small smooth fruits of *Myosotis sylvatica* and *Panicum diffusum* were retained for the longest period. Of the fruits and seeds which passed through the intestine of one or other of these birds, 75 per cent germinated in the case of the blackbird, 85 per cent in the case of the thrush, 88 per cent in the case of the rock-thrush, and 80 per cent in the case of the robin. The germination of fruits and seeds that had undergone ingestion and excretion was usually (*i.e.* in from 74 to 79 per cent of the cases) tardy as compared with that of similar fruits and seeds which had not been treated in this way but were only germinated for the purpose of comparison. Only in the case of a few berries (e.g. *Berberis, Ribes, Lonicera*) was the period of germination hastened. The seeds of such plants as grow on richly-manured soil (e.g. *Amaranthus, Polygonum, Urtica*) after passing uninjured through a bird's intestine produced stronger seedlings than did those which were cultivated without such preliminaries.

From these experiments it is evident that the dispersion of edible fruits through the agency of thrushes and blackbirds is not, as was formerly supposed, an exceptional phenomenon obtaining in the Mistletoe only, but one that may take place in the case of many other plants, and other observations prove that, as a matter of fact, it does take place. Plants possessing fleshy fruits are undoubtedly often disseminated in this manner. The occurrence of such plants as epiphytes upon trees, and also their unexpected appearance on the tops of high rocks and old walls thus receives a natural explanation.

The phenomenon in question also enables us to interpret the meaning of the changes undergone by fleshy fruits at the season when their dispersion becomes desirable, inasmuch as they serve the purpose of attracting animals, and the same consideration applies to the contrivances whereby animals are discouraged from taking the fruits before they are ripe. Mention has already been made of these latter contrivances on p. 444; and as regards the attraction of animals with a view to the dispersion of ripe fruits the following particulars are of especial interest: Fruits and seeds that are still unripe are hidden amongst the leaves of the mother-plant, have a green colour resembling that of the foliage, and are destitute of scent. On ripening the fruits are exposed, the coats of the fruits acquire a conspicuous coloration, and frequently emit a strong scent. In the cases where the seeds alone are dispersed and the pericarps are left behind, as, for instance, in *Pœonia Russi*, *Euonymus verrucosus* and *Magnolia grandiflora*, the capsules or follicles burst open, and the seeds are of a bright red or yellow colour, sometimes flecked with steel-blue and black, which renders them visible from afar. In the above-named species of *Euonymus* and *Magnolia* they emerge from the pericarps and hang at the ends of threads which renders them even more conspicuous. The particular colour assumed by fruits and seeds at the time of maturity varies according to that of the foliage by which they are surrounded. The different tones of red stand out best from a green environment; therefore, for plants with evergreen foliage (e.g. *Ardisia, Gaulteria, Ilex, Taxus, Arbutus Unedo, Arctostaphylos uva-ursi, Vaccinium Vitis-Idœa*) a red coloration is the most advantageous. Also in the case of plants with foliage which, although not evergreen, does not acquire an autumnal tint at the season when the fruits are ripe, *e.g.* the Strawberry, the Raspberry, the Currant, the Wild Cherry, and the Red-berried Elder (*Sambucus Ebulus*) the red hue of the fruits is of great value. On the other hand, red fruits would stand out but little against a background of foliage that had already donned the red or yellow tints of autumn by the time they ripened, and accordingly the fruits of *Ampelopsis hederacea, Cornus sanguinea, Prunus Padus, Arctostaphylos alpina, Vaccinium Myrtillus* and *V. uliginosum*, &c., are, as a fact, blue or black. Sometimes the fruits are black and the fruit-stalks red, as in *Sambucus nigra*, or the fruits are only coloured on the side exposed to view, as in the Apple and the Pear. The fruits of the Quince and the Pine-apple are set off by their yellow colour from the blue-green foliage. White berries, such as those of *Cornus alba* and *Symphoricarpus*, occur principally in plants which cast their leaves before the fruit is ripe. Standing out against the brown or gray baekground formed by the leafless branches and the fallen leaves of late autumn these white fruits are clearly visible. The extent to which fruits are advertised by their scents is a matter of common experience, and we need only refer for illustration to the Strawberry, the Raspberry, the Quince, and the Pine-apple.

Seeing that the seeds and stones containing seeds of the fleshy fruits eaten by thrushes and blackbirds only remain a short time in the crop and intestine of the bird, it is probable that the plants in question are disseminated by this agency to

the distance of a few leagues at most, in the course of a single year, and that it takes many years to distribute them, step by step, as it were, over large areas. We may reasonably suppose that distribution is effected principally in the direction of those parts of the world towards which thrushes and blackbirds are in the habit of journeying by short daily stages when autumn, the season of the maturity of most fleshy fruits, sets in.

It is well known that nutcrackers, jays, squirrels, and marmots, keep stores of food in larders, which they fit up in holes in rocks or in the earth or in some other secret hiding-place of the kind, and that such fruits and seeds as they conceal there are liable to be left permanently for one reason or another. The hiding-place may be forgotten, or, as is still more likely, the creature that occupied it may fall a victim to a bird of prey. The fruits and seeds may then germinate in the place of concealment, and, inasmuch as the latter is always more or less distant from the spot whence the fruits were taken, this must also be accounted one of the modes of dispersion of the plants in question. I have myself observed this curious phenomenon also in the case of the dissemination of the Arolla Pine (*Pinus Cembra*) by nutcrackers, of Beeches, Oaks, and Hazels by jays, and of Hazels by squirrels.

The subject of the dispersion of seeds by insects may be most conveniently dealt with in this connection. Otto Kuntze observed how ants fasten on to the pulp which surrounds the seeds of *Carica Papaya*, and push the seeds before them in companies of three, and Lundström narrates that the seeds of the Cow-wheat (*Melampyrum*), after they fall out, are carried off to ant-hills. These statements early directed my attention to the subject of the dispersion of seeds by ants, and I found that the phenomenon occurs on a very large scale. The ant *Tetramorium cæspitum*, in particular, is indefatigably engaged throughout the summer in dragging seeds to the ant-hill and storing them up there. Other species, which live in holes in the earth, hollow trees, and such places (*Lasius niger*, *Formica rufibarbis*, &c.), exhibit this form of activity, but they are much more fastidious than *Tetramorium*. Many kinds of seed, which are at once pounced upon by the last-named if they are scattered in the path of those insects, are left untouched by other species. So far as my observations go, it is the seeds with smooth external coats, but with large micropylar and hilar caruncles (see p. 425) which are conveyed to the holes, as, for instance, those of *Asarum Europæum* and *A. Canadense*, *Chelidonium majus*, *Cyclamen Europæum*, *Galanthus nivalis*, *Möhringia muscosa*, *Sanguinaria Canadensis*, *Viola Austriaca* and *V. odorata*, *Vinca herbacea* and *V. minor*, and various species of the genus *Euphorbia*. The *Tetramorium* showed a preference for the seeds of *Sanguinaria Canadensis*, which possess a very conspicuous hilar caruncle. These seeds being comparatively large and heavy, three or four small ants join forces when one is to be transferred to a hole. There can be no doubt that the caruncle, affording as it does an easily accessible supply of food, constitutes the source of attraction to the ants, and induces them to carry off those particular seeds. Neither the smooth coats of the seeds nor their contents are touched by the ants. Only thus can we interpret the fact that the seeds

dragged by ants under the ground, or into crevices in walls, germinate in those situations in the following year. It sometimes happens also that here and there a seed is left behind on the route of the ants, and in that case the caruncle is usually eaten off. Such abandoned seeds likewise germinate in the following year, and this explains the fact that the routes traversed by ants are regularly planted with certain species of plants. For example, in the Botanic Gardens at Vienna, the presence of *Chelidonium majus* is a constant feature of the ant-runs.

The transport of fruits and seeds to spots more or less remote from the localities where the mother-plants grow, by animals which have a definite purpose in view in so conveying them from one place to another, is on the whole a rare means of dissemination, and is confined to comparatively few species. But the unintentional dispersion of fruits and seeds by animals is of much more common occurrence. The objects thus dispersed get stuck or hooked, or otherwise fastened to the animals in the course of the latter's wanderings, and sooner or later are got rid of by them as being an unpleasant encumbrance. The places where such fruits and seeds are deposited are, however, always more or less distant from the spot where they ripened, and, as a general rule, they afford favourable conditions for germination.

The adhesion of fruits and seeds to the feathers of birds and to the skin or fur of other animals is due either to the agency of water, mud, and moist earth, or to that of special sticky substances secreted by the plants. In the case of many aquatic and marsh plants, such as the genera *Alisma, Butomus, Carex, Myriophyllum, Phellandrium, Polygonum, Potamogeton, Sagittaria,* and *Sparganium,* the fruits and seeds are unprovided either with special organs of attachment or with viscid secretions, but as was mentioned on p. 847 they have the power of keeping afloat on the surface of the water. If one dips one's hand into a pond covered with floating fruits of this kind, and draws it out again quickly, a number of the fruits always adhere to the skin by means of drops of water. The same thing happens when water-fowl rise from the water after swimming about for a time. The beak, legs, and feathers of a bird that has been shot not infrequently have the fruits in question clinging to them after the water has run off. If the bird had settled upon another pond the fruits would no doubt have been transferred to it. Adhesion through the intervention of water is assuredly by no means an insignificant factor in the dispersion of fruits to moderate distances.

The agency of mud and wet, boggy earth in affixing objects to animals is especially efficacious in the case of the numerous small fruits and seeds, which are by this means caused to adhere to birds when they come to the water's edge to drink. Jackdaws, herons, and snipe are not very particular about cleanliness, and they are invariably found to be smeared with mud. Swallows, particularly the rough-footed species, are very important members of this category, as during their sojourn on the banks of rivers and ponds they get bespattered with particles of mud. It is true that they try to cleanse themselves from all such foreign matter, but when the season for migration approaches they become restless and excited and forget the morning toilet which, until then, is performed with great care. In the same manner

water-fowl when they migrate neglect their usual habit of assiduously removing all traces of dirt, and we know from the investigations made by Darwin how great is the number of seeds imbedded in the mud. From $6\frac{3}{4}$ ounces of mud 537 plants germinated. In my own case the examinations of the mud obtained from the beaks, feet, and feathers of swallows, snipe, wagtails, and jackdaws resulted in about half as productive a yield of fertile seeds; but that is a sufficiently striking result; and when it is remembered that pigeons and cranes traverse from 60 to 70 kilometres in an hour, whilst swallows and peregrine falcons cover as much as 180 kilometres, it is clear that fruits and seeds affixed to these birds may be carried in a very short time over several degrees of latitude. The number of species of plants which are dispersed in this manner is, it is true, but small. For the most part they are water-side and of these chiefly small annual species, as is evident from the following list of those whose fruits and seeds I found most frequently in the mud taken from birds:

Centunculus minimus.	*Heleocharis acicularis.*	*Lythrum Salicaria.*
Cyperus flavescens.	*Isolepis setacea.*	*Nasturtium amphibium.*
" *fuscus.*	*Juncus bufonius.*	" *palustre.*
Elatine Hydropiper.	" *compressus.*	" *sylvestre.*
Erythræa pulchella.	" *lamprocarpus.*	*Samolus Valerandi.*
Glaux maritima.	*Limosella aquatica.*	*Scirpus maritimus.*
Glyceria fluitans.	*Lindernia pyxidaria.*	*Veronica Anagallis.*

Most of these species are distributed over all parts of the world, but they seldom remain for a long time in any particular locality. They often start up quite unexpectedly at places where migrating birds have rested and gone to drink. The extraordinary occurrence on the edges of ponds in Southern Bohemia of the tiny *Coleanthus subtilis,* which is indigenous to India, and the sudden appearance of the same species of grass in the West of France about twenty years ago may be unhesitatingly attributed to the mode of dispersion in question, as may also the occurrence of the tropical *Scirpus atropurpureus* on the shores of the Lake of Geneva and that of the Southern native *Anagallis tenella* on the shores of the Schwarzsee at Kitzbühel in North Tyrol.

The instrumentality of rain-soaked earth on steppes, on ploughed fields, and on roads in sticking numbers of fruits and seeds to animals' feet, whether the latter be in the form of hoofs, claws, or toes, or to their hair or feathers, as the case may be, has been the subject of repeated investigation. In the hardened earth taken from the feet of birds Darwin found a large number of seeds, of which many germinated. Many weeds which grow on fields and roadsides (*Prunella vulgaris, Malva rotundifolia, Potentilla anserina, P. reptans, P. supina, Ranunculus sardous,* &c.) depend mainly on this mode of dispersion. According to an informant, the suckers of the Gecko (a kind of lizard adapted to running about on smooth rocks and walls) are sometimes beset with fine seeds, and there can be no doubt that certain plants may be disseminated by such means over steep declivities of rock.

The excretion of sticky substances by fruits and seeds themselves must naturally

promote their becoming attached to animals. Although the adhesive materials mentioned in vol. i. on p. 615 as exuding from the fruits and seeds of various Composites, Crucifers, Labiates, and Polygonaceæ when they are wetted may be primarily devoted to fixing those structures to a substratum where they can germinate, they also frequently serve a second purpose in sticking them to passing animals. The best instance of this is afforded by the Meadow Saffron (*Colchicum*), whose seeds stick to the feet of cows, sheep, and horses by means of a comparatively large caruncle, which becomes viscid when it is wetted; in this manner the seeds are conveyed from one pasture to another. There is also an instance that has come under my own observation of a small owl (*Athene noctua*), which, in catching mice, brushed against Wormwood bushes (*Artemisia*), and when it flew away was all besmeared with the fruits, which had been rendered sticky by a previous shower of rain. The succulent berries of *Bryonia, Lycium, Solanum,* and various other Cucurbitaceæ and Solanaceæ burst on the slightest touch when they are over-ripe, and sometimes their seeds stick to the hairs and bristles of passing animals, and it seems not improbable, from the reports of travellers, that the fleshy Rafflesias, which are found principally on the routes frequented by large pachyderms, are disseminated in the same manner. The mode of dispersion of the seeds of *Nuphar* and *Nymphæa* is also very curious. Their dissemination by aqueous currents has been already dealt with on p. 848, but they are besides conveyed from pond to pond by water-fowl. In order to obtain the nutritious seeds these birds break open the fruits of Water-lilies with their bills, and in so doing are almost sure to leave some of the seeds, which are imbedded in a slimy mass, sticking to the feathers surrounding their bills. If they are suddenly disturbed at their meal they have not time to clean their bills before flying away, and so they carry the seeds with them, and do not rub them off till they reach another pond.

The fruits and seeds of several plants attach themselves to any animals that happen to brush against them by means of special glandular hairs or stalked glands. These latter consist of round cells or groups of cells which are borne on stalk-like structures springing from the epidermis, and which produce on their surfaces viscid, slimy, and resinous substances (see figs. 476 [2] and 476 [5]). The most diverse parts may be clothed with stalked glands. In *Boerhavia, Adenocarpus,* and *Pisonia* (see fig. 476 [4]), it is the pericarp; in *Salvia glutinosa* (fig. 476 [1]), and the various species of the genus *Plumbago,* such as *Plumbago Capensis* (fig. 476 [3]), it is the calyx; and in *Linnæa borealis* (figs. 476 [6] and 476 [7]) it is a pair of bracts closely adherent to the fruit that is beset with stalked glands. In all these plants an absciss-layer is formed in the tissue of the fruit-stalk, and as soon as adhesion takes place the fruit is severed from the plant at the region of this separating or absciss-layer. Many plants—as, for example, the annual *Cerastium glutinosum*—have glandular hairs all over them, and when the seeds are ripe and the plants partially withered and only loosely rooted in the ground, a touch is sufficient to cause leaves, stems, and fruits to stick to the hair or feathers of any animal that may happen to pass. We may add that, in the case of every plant above referred to for illustration, the

phenomenon in question is not merely a matter of conjecture, but has come actually under observation.

About 10 per cent of all Flowering Plants possess fruits or seeds which are dispersed by means of clawed or barbed processes. This mode of dissemination is very like that whereby sticky fruits attain the same object. The part of the plant which is provided with these structures hooks on to the hairs, bristles, or feathers of any bird or other animal that happens to come into contact with it. The consequence is that it is torn away and carried off by the animal. This act of depredation is of course not intentional on the part of the creature that performs it; on the contrary, such appendages are a source of discomfort, and are got rid of as soon as

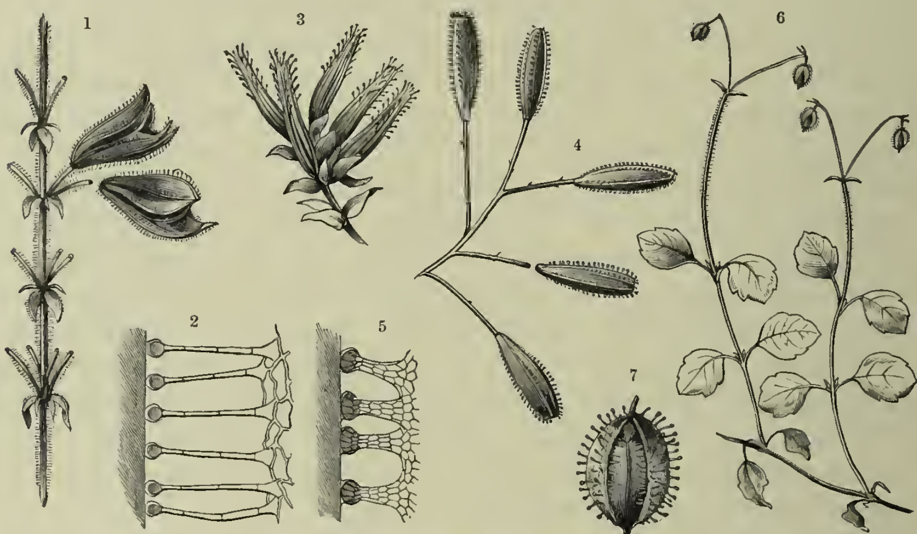


Fig. 476.—Sticky fruits.

1 *Salvia glutinosa.* 2 Stalked adhesive glands on the fruiting calyx of the same; ×60. 3 *Plumbago Capensis.* 4 *Pisonia aculeata.* 5 Stalked adhesive glands on the fruit of the same; ×60. 6 *Linnæa borealis.* 7 Fruit of the same; ×5.

possible. But in many cases this is not accomplished until a considerable distance has been traversed, and sometimes the troublesome objects remain for weeks in the creature's coat or mane. The organs of attachment are either hooked at the tip or beset with barbs (see figs. 477 [2] and 477 [18]). In the latter case the barbs are borne on special rigid bristles or needles, and are either collected together at the top, as in a harpoon, or else are arranged in longitudinal rows as in a hackle for combing flax. Only in a few instances (*e.g.* in *Polygala glochidiata, Stellaria glochidiata,* and *Limnanthemum nymphœoides*) do these structures, which may be classed together as hooked bristles and hooked prickles, occur on the seeds themselves; usually they are appendages of the pericarp, and as such exhibit every degree of size possible, from the delicate, hooked bristles on the small nutlets of the Enchanter's Nightshade (*Circœa,* see figs. 477 [8] and 477 [9]) to the thick, firm claws on the fruits of the African Harpoon Fruit (*Harpagophytum procumbens*). The hooked spines of the latter fruits attain to the size of crows' feet, and are a notorious source of vexation to

ruminant animals, both wild and tame. In the Transvaal and on the Orange River the spring-boks sometimes tread upon them unawares, and when that happens the sharp claws grasp the hoof and the animal is driven to frenzy by the pain and gallops madly away, but is unable to set itself free from the instrument of torture. It is often several days before the capsule breaks up and falls off. The fruits, which

Fig. 477.—Fruits furnished with hooks.

[1] *Galium Aparine.* [2] Hooked bristles of the fruit of the same. [3] *Hedysarum Canadense.* [4] A piece of the lomentum of the same. [5] Hooked bristles of *Hedysarum Canadense.* [6] *Cynoglossum pictum.* [7] Hooked prickles on the fruits of the same. [8] *Circæa Lutetiana.* [9] Hooked bristles on the fruit of the same. [10] *Torilis Anthriscus.* [11] Single fruit of *Torilis Anthriscus.* [12] Curved prickles on this fruit. [13] *Lappago racemosa.* [14] Single fruiting spike of the same. [15] *Setaria verticillata.* [16] Fruit-bearing branchlet with involucral bristles from a spike of *Setaria verticillata.* [17] *Bidens bipinnata.* [18] Single fruit of the same. [19] Fruit of *Caccinia strigosa.* [20] Hooked prickles on the fruit of *Caccinia strigosa.* [2], [4], [6], [7], [9], [11], [12], [14], [16], [18] and [20] magnified.

are armed with hooked bristles or prickles, are so numerous that even a superficial account of them cannot be undertaken here, and we must content ourselves with mentioning a few of the most remarkable forms. Amongst these are the capsular fruits of *Krameria Ixina* and *Triumfetta Plumieri* (see figs. 478[10] and 478[11]), the sheathed achenes of several species of *Calligonum* and *Rumex*, e.g. *Rumex nepalensis* (fig. 478[3]), the pods of many Papilionaceæ (e.g. *Medicago agrestis* and *M. radiata*, *Onobrychis æquidentata* and *Hedysarum Canadense*; see figs. 478[2] and 478[9], and

figs. 477 [3, 4, 5]), the nutlets of several Boraginaceæ (e.g. *Echinospermum*, *Cynoglossum*, and *Caccinia*; see figs. 477 [6, 7, 19, 20]), the several segments of the lomenta of *Æschynomene patula*, the jointed siliquas of *Tauscheria lasiocarpa*, the schizocarps of some species of the genera *Asperula* and *Galium* (e.g. *Galium Aparine*; see figs. 477 [1] and 477 [2]), and the mericarps of many Umbelliferæ (*Caucalis*, *Daucus*, *Orlaya*, *Sanicula*, *Torilis*; see figs. 477 [10, 11, 12], and figs. 478 [6]). Other contrivances exist, but are much rarer. Such are the bending of the sepals, when the fruit is ripe, so as to convert the calyx into a claw, as in the genus *Rochelia* (see fig. 478 [8]), the assumption by the teeth of the fruiting calyx of the form of hooked prickles, as in *Valerianella echinata* and *V. hamata*, *Trifolium spumosum*, *Ballota rupestris*, and *Marrubium vulgare* (see fig. 478 [1]), the presence on the achenes of Composites of 1, 2, 3, or 4 hooked prickles in the place of a feathery pappus, as in *Bidens bipinnata* (see figs. 477 [17] and 477 [18]), the barbed character of some perianth-bristles, as in *Scirpus lacustris*, and the crowning of the hypanthium (expanded receptacle) with hooked prickles, as in *Agrimonia* (see fig. 478 [5]). As instances of the transformation of involucral leaves into hooked bristles or prickles, we may mention *Xanthium* and *Lappa* (see figs. 478 [13] and 478 [17]); whilst *Oryza clandestina*, *Paspalum tenue*, and *Lappago racemosa* (see figs. 477 [13] and 477 [14]) may be taken as representatives of the Grasses whose glumes are furnished with similar appendages.

Sometimes the entire fruit has the appearance of a claw, or is armed with large barbs, by means of which it attaches itself to passing animals. This form of adaptation is especially striking in the pods of *Krameria triandra*, *Ornithopus*, *Biserrula*, *Coronilla scorpioides*, and *Scorpiurus sulcata* (see fig. 478 [4]). The achenes of several Composites (e.g. *Rhagadiolus stellatus* and *Koelpinea linearis*) are claw-shaped, and *Koelpinea linearis* is provided in addition with a crown of sharp, curved barbs at the free extremity of each limb of the claw. In several species of the genus *Geum*, of which *Geum urbanum* will serve as an example (see figs. 478 [15] and 478 [16]), the terminal portion of the segmented style breaks off when the fruit is ripe, and the remaining part becomes converted into a hooked spine which attaches itself to any object that happens to touch it. Similarly, hooked structures are developed from the styles of several Ranunculaceæ and Pedaliaceæ. Of the latter the most noteworthy are the fruits of Martynias (*Martynia lutea*, *M. proboscoidea*, &c.), which detach themselves from the herbaceous stem when the fruit is ripe—the stem being by that time in a decaying condition—and lie loose upon the ground. Two long curved clasps, with sharp hooked ends somewhat like the horns of a chamois in form, are developed from the styles, and by means of these the fruits cling to the feet of animals which tread on them. Indeed the whole family Pedaliaceæ is of interest on account of its multifariously hooked fruits. In addition to *Martynia* the already mentioned *Harpagophytum* belongs here, and several other genera, including a Chinese aquatic, *Trapella sinensis*. In this plant the fruit is provided with 3 long appendages wound up like watch-springs, which must readily hitch themselves on to the legs of aquatic birds—or possibly even to Fishes—and in addition 2 shorter, sharp, stiff spines, which no doubt preserve the fruits against

being eaten. *Rogeria* and *Pedalium*, mentioned on p. 875, also belong to this family.

In other plants it is the fruit-stalk instead of the style which is transformed into a claw-like structure. In *Cyclamen Europæum*, for instance, the fruit-stalk undergoes spiral torsion and contraction. Formerly it was supposed that the object of this curious phenomenon was to draw the fruits into the earth, where the seeds would be favourably situated for germination. But this idea does not correspond to actual fact. The green capsules are drawn underground in the late autumn

Fig. 478.—Fruits with hooks.

[1] *Marrubium vulgare.* [2] *Medicago agrestis.* [3] *Rumex nepalensis.* [4] *Scorpiurus sulcata.* [5] *Agrimonia odorata.* [6] *Orlaya grandiflora.* [7] *Pteranthus echinatus.* [8] *Rochelia Persica.* [9] *Onobrychis æquidentata.* [10] *Triumfetta Plumieri.* [11] Hooked bristles on the fruit of *Triumfetta Plumieri* magnified. [12] *Medicago radiata.* [13] *Xanthium spinosum.* [14] *Ceratocephalus falcatus.* [15] *Geum urbanum.* [16] A single fallen fruit of *Geum urbanum.* [17] *Lappa major.*

when the seeds are still unripe. They pass the winter in the earth, and do not attain to complete maturity until the following summer. The desiccation and severance of the twisted fruit-stalk then has the effect of pulling the fruit out of the ground again, the lower portion of the stalk rots, and the part which is left forms a claw surmounting the capsule. The latter, which is still full of seeds, lies loose on the ground, and adheres to the foot of any animal that treads on it. The manner in which these seeds are besides dispersed by ants has already been referred to on p. 866.

With this curious form of fruit we may associate those in which the claws or hooked prickles are metamorphosed branches, or parts of abortive flowers situated on special ramifications. It will be sufficient to adduce two examples of this group, viz., *Pupalia atropurpurea*, of the family Amaranthaceæ, and *Pteranthus echinatus* (see fig. 478 [7]) of the family Paronychiaceæ. In *Pupalia atropurpurea* short branchlets spring from the axils of the bracts; a few of them bear fruits, whilst the majority are modified into hooked prickles and form a tuft which easily fastens on to foreign bodies, and becomes detached from the main axis. *Pteranthus echinatus* has several short branchlets in each inflorescence situated close to the fruit, and bearing at their extremities abortive flowers with hooked sepals.

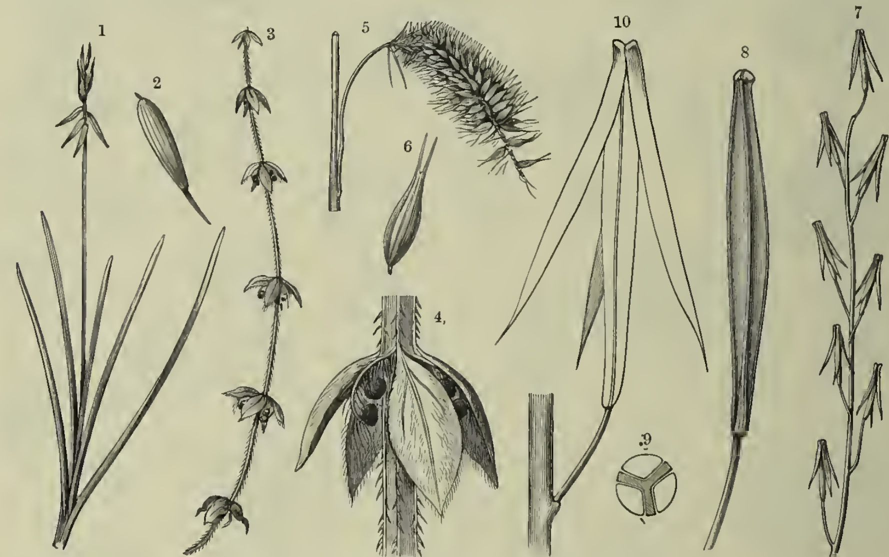


Fig. 479.—Fruits which hook on to or stick into passing objects.

[1] *Carex microglochin.* [2] Single fruit of the same. [3] *Galium retrorsum.* [4] A piece of the stem of the same. [5] *Carex Pseudocyperus.* [6] Single fruit of the same. [7] *Triglochin palustre.* [8] Single unripe fruit of the same. [9] Transverse section through the same fruit. [10] Single ripe fruit with its component valves separated. [2], [4], [6], [8], [9] and [10] magnified.

All the clawed or prickly fruits and clusters of fruit above enumerated easily come away from the mother-plant when pulled by the objects to which they have attached themselves. But there are other cases where the hooks and claws are firmly attached to the axis of the plant as a whole, so much so indeed that if the object to which they are fastened gives a pull a large piece of the stem is torn away, and sometimes even the entire plant is uprooted and carried bodily away. To this class belong the fruits of several Rubiaceæ, of which *Galium retrorsum* (see figs. 479 [3] and 479 [4]) may be taken as a type. The fruit-bearing stem of this plant is at once broken off or uprooted when its barbed bristles catch in the coat of a passing animal. The species of the genus *Uncaria* also are examples of the kind. The long, creeping stems develop here and there clusters of fruit and at other spots abortive peduncles, which are metamorphosed into strong, sharp claws. When these claws get hooked to an animal's foot, a more or less large piece of the stem is torn away, and with it

the fruits developed upon it. Again, in *Specularia falcata, Valerianella echinata, Cornucopia cucullata,* and *Ceratocephalus falcatus* (see fig. 478 [14]) the fruits do not sever themselves from the stems when their claws become attached to animals, but the entire plant is uprooted and carried away. A similar phenomenon is observed when a fruiting plant of *Setaria verticillata* is touched by one of the larger birds or some other animal. The fruits of this Grass are wrapped in awnless glumes and surrounded by involucral bristles furnished with very sharp barbs (see figs. 477 [15] and 477 [16]). When the bristles get fastened to an animal, not only the fruiting spike, but often a piece of the haulm as well, is dragged away, and sometimes the entire plant is uprooted and taken off. Such fortuitous appendages are very troublesome to the animal, and are got rid of as soon as possible. In many instances this is achieved without great difficulty by rubbing the coat against fixed objects, or by using the feet, snout, or beak, as the case may be, to disembarrass the body. Sometimes, however, the sharp claws and barbs of the fruits are so firmly imbedded

Fig. 480.—Fruits with needle-like spines.

1 *Pedalium Murex.* 2 *Tribulus orientalis.*

or entangled in the hair or feathers that their extrication is attended with much difficulty and suffering.

A mode of fruit-dispersion involving still greater pain to animals is that which is accomplished by means of straight, smooth prickles projecting from the fruit, and so situated as either to bore into the foot of any animal that treads upon it, or to stick into the coat of one that merely brushes by. Two groups of these fruits may be distinguished. The first group comprises those which lie loose upon the ground when they are ripe. To it belong *Acicarpha, Ceratocarpus, Salsola,* and *Spinacia,* in which the tips of the fruiting calyx harden and are transformed into spines standing straight up, and also *Rogeria, Pedalium,* and *Tribulus* (see figs. 480 [1] and 480 [2]), in which the spines project from the fruit-walls. One of the species of the last-named genus, viz., *Tribulus orientalis,* is of common occurrence in the lowlands of Hungary, and is an object of dread to the shepherds of that region. The fallen segments into which the fruit resolves itself are armed with hard, sharp, comparatively long spines, and are often so covered with drifted sand that only the tips of the spines project above the surface (see fig. 480 [2]). These prickles pierce deep into the hoofs and soles of animals that tread upon them, and are broken off the fruit by the efforts of the latter to rid themselves of the impediment. They are thus left sticking in the skin, and cause very painful, festering wounds. As examples of the second group of fruits furnished with sharp prickles as instruments of dissemination we

may take those of *Carex pauciflora* and *Triglochin palustre* (see figs. 479 [1, 2, 7, 8, 9, 10]) These fruits are borne on a stiff, erect axis, and when ripe are pointed obliquely downwards. They easily become detached from their stalks and are left sticking like needles in the skin or fur of animals that touch them.

Straight or slightly curved bristles and prickles may take part in another way in the dispersion of fruits. When they are set in rows like the teeth of a comb on the surface of a fruit or stand out in pairs from it, as, for instance, in *Carex Pseudocyperus* (see figs. 479 [5] and 479 [6]), the woolly hairs and delicate feathers of some animals are liable to get entangled in them, and they are then dragged from their stalks. The same thing happens where the prickly processes projecting from the fruit cross one another, as in *Pterococcus, Sycios,* and many species of the Medick genus (e.g. *Medicago ciliaris, M. littoralis, M. sphærocarpa, M. tentaculata,* and *M. tribuloides*), and where the surface of the fruit or of the fruiting calyx is covered with stiff bristles forming acute angles with it, as in *Asperugo, Myosotis, Parietaria, Physocaulis,* and *Torilis* (see figs. 477 [10, 11, 12]). In many Grasses the awns which project from the backs of the glumes act as instruments for catching the hair of animals as they pass, and the latter is also liable to get caught between the nut and the hardened perianth-segments which surround it in several Chenopodiaceæ. It is not necessary for this that the bristles, prickles, or awns should be pointed, but it is advantageous for their surfaces to be rough or jagged, as in *Torilis* (see fig. 477 [12]). We must not omit to mention also that the tufts of hair which clothe some fruits and seeds, and act as parachutes and wings, often get entangled in the hair or feathers of animals, and thus play an additional part in dissemination. The rough coats of sheep, goats, oxen, and horses are always found to have such hairy fruits and seeds affixed to them after they have passed over ground on which herbaceous Composites, shrubby Willows, &c., grow at the season when those plants are in fruit. I have myself removed from the coats of animals of the above-mentioned kinds fruits and seeds of *Anemone sylvestris* and of various species of the genera *Calamagrostis, Crepis, Cynanchum, Epilobium, Eriophorum, Lactuca, Lagœcia, Micropus, Populus, Salix, Senecio, Sonchus,* and *Typha.*

Anyone who has forced his way through a thicket of poplars and willows in early summer or through a clearing overgrown by *Calamagrostis, Epilobium,* and *Senecio* in late summer can bear witness to the manner in which fruits and seeds of the sort in question adhere to the clothes. Sticky and hooked fruits are also found upon one after such excursions, and it is perhaps not superfluous to remark that what has been said concerning the dispersion of seeds by animals must be taken to apply also to dissemination by men. Of course we are here referring to *unintentional* dissemination by human agency. We are here concerned with the cultivation of corn, vegetables, garden-flowers, edible fruits, forest-trees, &c.—*i.e.* with the purposeful dispersion of plants by men—in so far as many of the species in question establish themselves beyond the limits of the fields or gardens, where they have been sown or planted by man, through the operation of their natural means of dissemination and without human assistance, and further, inasmuch as weeds are often

introduced into the soil unawares with the seeds of other plants, and so grow in places where they would scarcely ever obtain a footing without the interference of mankind.

Looking back over this chapter we are struck by the following points:—In the first place, the commonest contrivances and adaptations are those which confer some other benefit in addition to that of dispersing fruits and seeds. The kind of structure most often encountered in this connection serves first as a means of protecting the flowers against unbidden guests of the animal kingdom and against injurious climatic conditions, subsequently as a means of scattering the fruits, and lastly, is instrumental in attaching them to a substratum and in promoting germination. Moreover, it appears from what has been said concerning pappuses and tufts of hair, that it is no rare thing for contrivances to be adapted equally well to the dispersion of fruits and seeds by the wind, by water, or by animals. It is also of great moment to observe that most, and perhaps all, Phanerograms exhibit two methods of disseminating their fruits and seeds, one of which is adapted to considerable distances, whilst the other is confined to the immediate vicinity of the mother-plant. The former may and does, as a fact, take place on a vast scale, but it depends upon the circumstances of the environment over which the plant itself has no control. It may, therefore, in some circumstances, be completely suppressed; in other words, dispersion to a great distance may take place but does not necessarily take place. Just as the best-made machine stands still unless its wheels are set in motion by an impulse from without, so the development of the most perfect flying apparatus is of no avail if there is an entire absence of wind at the time when the winged fruit is ripe; nor do the strongest hooks serve as means of dispersion if no animals come upon the scene. On the other hand, dissemination within short distances of the mother-plant always takes place if wider dispersion fails. Supposing the fruits of a Maple-tree, when ripe, are not blown far away by a strong gust of wind, they are ultimately detached spontaneously, and drop with a gyratory motion to the ground close by the tree which produced them. Again, in the case of the Squirting Cucumber, should the expulsion of the seeds from a fruit be caused by the touch of an animal, and the seeds stick to the latter's coat, they may be carried to a distance of many miles, but if no animal happens to pass the spot where the Cucumber is growing at the time when the seeds are ripe the latter are spontaneously ejected, and the dispersion so effected does not exceed a few paces in distance. In the event of the fruits of *Cyclamen* (see p. 873), which are borne on twisted claw-shaped stalks, not being carried away by animals, they remain lying on the ground in immediate proximity to the mother-plant and the seeds germinate in that situation.

These examples, to which might be added many others, show that the same law governs the contrivances adapted to the dispersion of fruits and seeds as was found to apply to the pollination of stigmas (see p. 390). Every species of plant exhibits some mechanism designed to bring about a cross with another species, or, at any rate, with another individual. If such mechanism is unsuccessful, other

contrivances are brought into play, the aim of which is to accomplish autogamy. The open flowers of *Viola sepincola* are adapted to cross-pollination through the agency of bees; should no cross take place, and no fruits be produced from the open flowers which bloom above the ground, cleistogamous flowers, hidden underground, develop and bring forth a number of fertile seeds as a result of the autogamy which inevitably takes place within their closed floral envelopes. *Viola sepincola* may also be taken as a type of those plants in which the fruits ripen underground and produce seeds which germinate at the spot where they were formed. Such plants have always been a source of wonder to botanists, and their number is not large. The best-known examples are *Arachis hypogœa, Cardamine chenopodiifolia, Linaria Cymbalaria, Phrynium micans, Trifolium subterraneum,* and *Vicia amphicarpa.* If these plants were only to bring fruits to maturity underground, or were to draw all their fruits below the ground as soon as the seeds were mature, in order that germination and the development of new plants might ensue at that spot, their behaviour would imply a renunciation of dispersion to any distance, and the phenomenon would be highly enigmatic. The puzzle is, however, satisfactorily solved when we take into account the fact that all these plants invariably have the chance of being dispersed to great distances either before the fruits become concealed in the earth, or by means of a second form of fruit which ripens above ground, and is evidently adapted to being scattered abroad through the agency of animals, or by means of aërial or aqueous currents.

LIMITS OF DISTRIBUTION.

The results of careful computations of the numbers of seeds produced yearly by a few selected plants show that on an average a plant of *Sisymbrium Sophia* yields 730,000, one of *Nicotiana Tabacum* 360,000, one of *Erigeron Canadense* 120,000, one of *Capsella Bursa-pastoris* 64,000, one of *Plantago major* 14,000, one of *Raphanus Raphanistrum* 12,000, and one of *Hyoscyamus niger* 10,000. Each of these seeds may give rise in the following year to a new plant, which, in its turn, may produce a corresponding number of seeds. Accordingly, if a Henbane-plant developed 10,000 seeds in one year, and 10,000 plants sprang from those seeds next year, and themselves produced 10,000 seeds each, by the end of five years ten thousand billions of Henbane-plants would have come into existence. Now, as the entire area of the dry land on the earth is approximately one hundred and thirty-six billion of square metres, and there is room for about 73 Henbane-plants on one square metre, if all the seeds referred to in our hypothesis ripened, the whole of the dry land would, at the end of five years, be covered with the plants in question. In the case of *Sisymbrium Sophia,* the normal multiplication, if unchecked, would, in the course of three years, cover an area 2000 times as great as the surface of the dry land with plants.

Any such exclusive occupation of the entire earth by one or a few species is prevented by a variety of causes. As regards land-plants, the sea, separating one

country from another, constitutes an important barrier to unrestricted distribution. Even narrow straits form an insuperable obstacle to any mode of dispersion which proceeds step by step, whilst broad seas also interfere with the dissemination *per saltum,* which is accomplished by roving animals and by currents of air and water. The number of species capable of being transported across the sea by birds is so small, that the dispersion of plants as a whole is not appreciably affected by this process. The same remark applies to dissemination by water. It is well known that fruits and seeds of American plants are occasionally conveyed to Europe by the Gulf Stream, and Linnæus tells us how the seeds of the West Indian Filbert (*Entada Gingolobium*) germinated after being stranded on the coast of Norway. There is no need to point out that tropical plants of the kind would not be able to establish themselves permanently in Western Europe were it only for the nature of the climate. But even amongst other American plants to which the climate would be no drawback, not a single species is known to have come to Europe by water without human intervention. Nor has any fruit or seed achieved the crossing of the ocean to Europe through the medium of the air. America possesses a large number of Willows, Composites, and Onagraceæ of her own, which have their fruits and seeds exquisitely adapted to aërial flight, and are themselves well fitted to thrive under the climatic conditions of Europe. Nevertheless not a single instance is recorded of such a plant migrating from America to Europe through the agency of the wind. The Compositæ and Onagraceæ, which have become naturalized in Europe since America was discovered (e.g. *Erigeron Canadense, Galinsoga parviflora, Solidago Canadensis, Stenactis bellidiflora, Œnothera biennis,* &c.), were introduced in other ways, and would neither have established themselves nor have been disseminated in Europe without human intervention.

The fact that a considerable number of American plants have found a home in Europe through the agency of man alone, and independently of the movements of birds or currents, is of great interest in connection with the present subject, inasmuch as it shows that the limits of distribution imposed by the sea are only temporary, that is to say, they are only maintained so long as the present distribution of land and water remains unaltered. If Europe and America were to become connected by a bridge of land, the possibility would arise of a gradual or sudden migration across the bridge, and such plants as have been conveyed from America to Europe by human agency would be able to immigrate without such assistance, and to disseminate themselves over Europe. The external conditions would offer no impediment to their naturalization in Central Europe any more than they now do to the installation of the same species when introduced by man. As the sea limits the distribution of land-plants, so the dry land restricts the dispersion of marine plants. The larger the expanse of land between two seas, the more difficult is it for the plants which inhabit them to exchange their homes. But here again the barrier is merely temporary; for were the land to sink in any part so as to become submerged, and the two seas thus become confluent, there would be nothing to prevent the plants living in them from passing from one to the other.

The nature of the soil may constitute an insuperable obstacle to a permanent occupation of a particular district by plants, and so act as a check to dispersion. Everywhere localities with sandy, loamy, or rocky subsoils alternate with loose, wet, and porous argillaceous earths. And yet how utterly different are the conditions under which plants growing on these two kinds of soil respectively must exist. Let us consider the case of a particular species, whose seeds are uniformly scattered over a district which includes areas with different kinds of soil. In the parts where the ground possesses the requisite properties for the maintenance of the species in question, the seedlings are able to establish a firm footing, whilst those seeds which fall on uncongenial soil perish. If millions of fertile seeds belonging to a marsh-denizen were scattered over a dry tract of land, not a trace of them would be found at the end of a twelvemonth. The extent to which the chemical in addition to the physical properties of the soil operate, in producing this result, and the part played by competition between different plants for possession of the ground, have been already dealt with (p. 495 *et seq.*). From these observations it is obvious also that the distribution of species, even within a district of restricted area, is materially influenced by the soil, and that the spots in such a district where a particular species thrives and multiplies are divided from one another by tracts where it does not exist. Those restricted sites in a locality, which offer favourable conditions to the progress of a particular species, and allow of its posterity maintaining possession of the soil, where, indeed, the species is permanently established are called the habitats of that species. The botanists of former times distinguished such habitats into a large number of different classes, from which we may select the following as the most important: fresh-water springs (*fontes*), salt springs (*salina*), brooks (*amnes*), torrents (*torrentes*), rivers (*fluvii*), pools (*stagna*), lakes (*lacus*), the sea (*mare*), shores of rivers and lakes (*ripæ*), sea-coasts (*littora*), marshes (*uliginosa*), swamps which dry up in the summer (*paludes*), peat-bogs (*turfosa*), places that are periodically flooded (*inundata*), pastures (*campi*), steppes (*pascua*), deserts (*deserta*), sunny hills (*colles*), stony places (*lapidosa*), rocky places (*rupestria*), sands (*arena*), argillaceous soil (*argilla*), loam (*lutum*), débris (*ruderata*). Sufficient has been said to prove the fact that these habitats undergo various displacements, and are sometimes entirely lost, in consequence of changes effected in the soil in course of time through the action of running water and aërial denudation, or in consequence of the accumulation of humus.

The most potent influence affecting the dissemination and distribution of plants is that exercised by climate. The length of the days and corresponding duration of the sun's illumination, the temperature of air, ground, and water at the different seasons of the year, the condition of the atmosphere in respect of moisture, the quantity of water deposited by the atmosphere, and the times at which such deposition occurs in each year, the strength and direction of prevailing winds—not only are all these circumstances in general of the greatest moment to plant life, but each climatic factor stands in a definite relation to each species. If the fruits or brood-bodies of a plant are carried by any of the usual agencies of dispersion to a place

where the soil is favourable, but where the intensity of light, of warmth, or of moisture exceeds or falls short of the right measure for that particular species, the development of the species is arrested at the outset, and the plants die without leaving any offspring behind them. In this manner an absolute barrier is opposed by climatic conditions to the dispersion of each species. It must be added that the check may be given in one direction by one factor and in another direction by another climatic factor, and that not infrequently many conditions, collectively classed under the name of climate, exercise a simultaneous influence on the distribution of species.

The limits to the range of plants towards the Arctic and Antarctic regions and towards the summits of high mountains are imposed by the diminution of temperature and the increasing length of the winter, whilst the opposite boundary is encountered where the duration of daylight is still too short at the time of year when the temperature begins to be sufficient to cause the plants in question to sprout. The continental climate, which is distinguished by slight degrees of moisture, high summer temperatures, and low winter temperatures, checks those plants which suffer from dryness in summer or which cannot endure the cold of winter. On the other hand, in the case of species whose transpiration is unduly checked by a high degree of atmospheric moisture and which require an elevated temperature in summer in order to bring their seeds to maturity, bounds are set to dispersion by the climate of the sea-coast where comparatively slight variations of temperature occur during the year and where the summers are cool and the air damp. Meteorologists show us on special charts the distribution of the climatic factors by connecting all places having the same mean winter temperature, the same mean summer temperature, the same mean annual deposition of moisture from the atmosphere, and so forth, by lines which are termed isocheimal, isotheral, and lines of like mean annual rainfall respectively. The distribution of plants, in so far as it depends on climatic conditions, may be shown in the same manner by drawing lines connecting all the places at which any species is checked by climatic conditions. Such lines are called lines of vegetation, and when they run along the slopes of a mountain they coincide with the contour-lines. As each species of plant is checked in its progress towards the different quarters of the compass by different factors of climate, lines of vegetation may be drawn corresponding to the limits of range for each species to the north, north-east, east, south-east, south, &c. When all these vegetation-lines of a species are connected we obtain a curve which returns upon itself and is called a line of distribution. In most cases this line resembles an ellipse with the longer axis lying in the direction of the parallels of latitude. It is, however, not infrequently modified by influence of the nearest lines of sea-coast. The proximity of mountains also may cause variations which are principally of the nature of sinuses or bulgings.

The line of distribution incloses therefore the entire area of distribution in which the species in question finds suitable conditions and in which as a fact it grows and multiplies. Emphasis must be laid on the latter circumstance, because experience has shown that a plant-species does not necessarily grow in all the places where the conditions are favourable to its existence. Only the boundary-lines of the area of

distribution are dependent at the present day on climatic conditions; the manner in which the species has come to occupy that area has not been determined by the existing climate, but by geological processes which have always been the cause of the migrations of plants on a large scale. It also becomes a question in each individual case to what extent under past and present conditions the means of plant-dispersion would have free play.

The different areas of distribution vary greatly in size. Many species are only encountered on a single mountain, or in a particular valley, or on one island, as the case may be. These are called endemic species. As examples of such endemic species from the regions of Southern and Central Europe we may mention the following: *Iberis Gibraltarica* (Gibraltar), *Euzomodendron Burgœanum* (Central Spain), *Dioscorea Pyrenaica* (Central and Eastern Pyrenees), *Saxifraga florulenta* (Liguria and Piedmont), *Saponaria lutea* (South-western Alps), *Heracleum alpinum* (the Jura), *Hieracium Grisebachii* (the Oetzthal in the Central Alps of Tyrol), *Daphne petrœa* (Val Vestino), *Rhizobotrya alpina* (Fassa and Belluno), *Gentiana Frölichii* (Carniola and Carinthia), *Wulfenia Carinthiaca* (Carinthia), *Sempervivum Pittonii* (Serpentine mountains in Upper Styria), *Schiverekia Podolica* (Podolia), *Viscaria nivalis* (Rodna Gebirge, in Northern Transylvania), *Pedicularis limnogena* (Bihar Mountains), *Hepatica Transsylvanica* (Southern Transylvania), *Haberlea Rhodopensis* (Rhodope Mountains in Roumelia), *Jankœa Heldreichii* (Thessalian Olympus), *Helichrysum virgineum* (Mount Athos), *Campanula Aizoon* (Mount Parnassus), *Hypericum fragile* (Eubœa), *Globularia stygia* (Mount Khelmos), *Genista Melia* (Melos), *Cephalanthera cucullata* (Crete), *Centaurea crassifolia* (Malta), *Petagnia saniculifolia* (Sicily), *Lereschia Thomasii* (Calabria), *Batatas sinuata* (Ischia), *Helichrysum frigidum* (Mountains of Corsica).

The species contrasting with the endemic as regards distribution, *i.e.* those whose range extends over almost the whole of the plant-inhabited earth, are called cosmopolitan. Their number is very small.

Only in the case of endemic species occupying an extremely restricted area do we sometimes find the plants evenly distributed over the whole area. They are more usually scattered unequally over the district in question. The spots where they grow in large numbers close together are separated by tracts where they do not grow at all, but where other species have taken possession of the soil, and the line of distribution then incloses separate habitats which are often at a considerable distance from each other. In such cases we speak of the area of distribution as sporadic. How far this depends on properties of the soil has been explained on pp. 495–500, and we need here only add that in mountainous or hilly countries the degree and direction of the inclination of the ground may have an important influence. Owing to the fact that a slope receives very different amounts of light and heat according as it faces north or south, different parts of a single mountain may exhibit diversities in respect of temperature and moisture as great as exist on flat ground between places separated by a degree of latitude. Also the differences in meteorological conditions between slopes facing east and west respectively, and

particularly those with south-east and south-west aspects, are much greater than is commonly supposed, and species are known, for example, which in a particular district invariably have their habitats on south-east slopes, whilst others occur only on slopes facing south-west.

It has been stated that the geological phenomena, and the changes of climate connected therewith, have at all epochs exercised an important influence on the migrations of plants, and have consequently had much to do with the displacements that have occurred in the lines of distribution. If a change occurs which results in the climatic conditions of 48° north latitude becoming such as previously prevailed at 46° north latitude, those species of plants whose range extended northwards as far as 46° proceed to take possession of suitable habitats beyond that limit and the northern line of vegetation of those particular species is sooner or later shifted northwards. On the other hand, the species which had up to that time enjoyed favourable conditions at 48° north latitude, but can no longer flourish under the new conditions, establish themselves on more suitable habitats lying further north, so that their southern line of vegetation undergoes displacement northwards. The eastern and western lines of vegetation may also be shifted in accordance with such alterations of climate as occur when an inland locality is converted into a maritime site or *vice versa*. These displacements may assume the aspect of a progression or of a retrogression, but in every instance the abandonment of the area of settlement will take the form of a migration of the plant-species concerned.

These migrations of plants which are accomplished independently of human influence take place as slowly or as quickly as the changes of climate to which they are due. In the case of species only capable of flourishing on particular habitats colonization must naturally proceed by leaps and bounds, whilst retrogression also cannot possibly take place uniformly.

The numerous habitats occupied by a species within the limits of its area of distribution are scarcely ever exactly alike in respect of the conditions which influence plant-life. Some habitats are pre-eminent on account of their advantageous position. The species in question develops most robustly, and multiplies most abundantly in that habitat. In the event, too, of a change of climate the species continues to live there longer than elsewhere, and may succeed in clinging to such isolated spots under fundamentally altered climatic conditions long after it has died out from hundreds of other habitats in the neighbourhood. If the species has meanwhile transplanted itself to adjoining territory and established there a fresh area of distribution, the spots where it has managed to survive in the old country appear like lost outposts wrested from the main area of distribution, or like islands lying off the shores of a continent. Such a state of things is by no means uncommon, and we are able to deduce therefrom facts not only concerning the former condition of the vegetable world, but also concerning the climatic conditions which used to prevail and as to the directions in which, in due course, plant-migrations have taken place. We shall have an opportunity to return to these interesting cases in the last chapter of this volume.

It is of great interest to note that the so-called "petites espèces" (see p. 581) of a particular genus often suppress and replace one another in adjacent regions and climatic zones. The first idea which suggests itself to one observing this phenomenon is that the differences of form exhibited by these races in neighbouring districts are the direct result of the diverse conditions of soil and climate under which they exist, and in former times this was the general opinion of botanists. Even at the present day many botanists hold the view that when a plant-species reaches a place where the climatic conditions differ from those of the home it has till then inhabited, it is able to adapt itself to the new environment, that such adaptation takes the form of an alteration of form, that the change is inherited by the plant's offspring, and that in this manner new species arise. But the results of experiments made on purpose to determine this matter do not justify any such opinion. No success has attended efforts to bring back various "petites espèces" to one and the same form by cultivation under precisely similar conditions, nor has any one of those species undergone the anticipated transformation on being transferred to the external environment which was looked upon as the cause of the variation in question. Either the species subjected to the new conditions succumbed thereto and perished without leaving any offspring, or else it underwent such alterations in form as are usually considered to be indicative of varieties merely (see pp. 508–514). These changes were not inherited by the offspring, and no "petite espèce" has ever arisen from a variation caused by properties of soil or climate. Such characteristics as are preserved by heredity, and constitute the essence of a species can therefore only have made their appearance, even in the case of "petites espèces", as a result of crossing. Whenever characteristics produced by a cross were in harmony with the climatic conditions of a district, the survival of the form which possessed those characteristics was assured. Such a form would be able to acquire through its offspring an area of distribution exactly co-extensive with the appropriate conditions of soil and climate. The two old species from which the new one sprang may both remain in the neighbourhood; it is, however, possible for one only of them to survive, and it is also conceivable that both should have died out. We must not forget in dealing with this question that the age of most species is much greater than was formerly considered possible, that in the case of the majority of species repeated displacements of the area of habitation have taken place since the species arose, that in the course of these displacements the species which belong to a single original stock, and are therefore allied in respect of the history of their evolution, have often been separated from one another, and that a proportion of them have perished and vanished altogether from the scene.

So long as two areas of plant-distribution, formed in adjacent zones or regions, do not touch anywhere, intercrossing between the denizens of those areas is very difficult, if not impossible, and even the "petites espèces" persist unchanged under such circumstances, and preserve their specific characteristics in their offspring. But even where the areas of distribution adjoin one another, and the distance between their native species constitutes no hindrance to cross-pollination, it is still possible

for two or more species to remain sharply marked off from one another owing to the fact of their flowering at different seasons. If the flowers of one species are already over when the other begins to bloom, no cross can take place between them under natural conditions. This obstacle to cross-pollination, which has been termed *asyngamy*, is the cause which enables very similar species sometimes to live close together without producing hybrids, and thus prevents the origin of new intermediate forms. For example, when *Aster Amellus* begins to bloom the flowers of the similar plant known as *Aster alpinus* are already over in the same locality, and again, at the season when *Solidago Virgaurea* unfolds its earliest blossoms, the flowers of the allied species *Solidago alpestris*, growing in the same neighbourhood, have already set their fruits. Such asyngamic species, of which mention has already been made on p. 510, are therefore found even in localities where their areas of distribution are contiguous, and even where those areas dovetail into one another, and where the various "petites espèces" grow together and transmit their specific characters unaltered to their descendants.

PLANT COMMUNITIES AND FLORAS.

Wherever the reign of nature is not disturbed by human interference the different plant-species join together in communities[1], each of which has a characteristic form, and constitutes a feature in the landscape of which it is a part. These communities are distributed and grouped together in a great variety of ways, and, like the lines on a man's face, they give a particular impress to the land where they grow. The species of which a community is composed may belong to the most widely different natural groups of plants. The reason for their living together does not lie in their being of common origin, but in the nature of the habitat. They are forced into companionship not by any affinity to one another but by the fact that their vital necessities are the same. It may perhaps be true that amongst the many thousands of plants inhabiting the earth no two are to be found which are completely alike in their requirements in respect of the intensity and duration of solar illumination, the concurrence of a particular duration of daylight with a certain amount of heat, the composition and quantity of the nutrient salts available at the places where the plants live, the amount of moisture in the air and in the ground, or, lastly, the character of the rainfall. This does not, however, exclude the possibility that in particular places similar demands may be met, and that different species with similar needs may flourish undisturbed side by side as men live together in one house or in one town, and, although their customs and their needs may not be exactly the same, yet form a society which is permanent and thrives, and wherein each member feels at home, because it rests upon common usages and is adapted to the local conditions. Nor is it impossible that each one may derive an advantage from the common life,

[1] *Cf.* A. Kerner von Marilaun "Oesterreich-Ungarns Pflanzenwelt", in *Die Oesterreichisch-Ungarische Monarchie in Wort und Bild.* Vol. i. p. 185 (1887).

that the associated individuals may support one another in the conduct of their lives, and that they may even be dependent upon one another.

A knowledge of the communities which exist within the realm of plants is of great importance in many ways. It throws a strong light, not only on the mutual relations of the different species which are associated by common or similar needs, but also on the connection of plant-life with local and climatic conditions and with the nature of the soil. It may fairly be said that in the various zones and regions of our earth no kind of phenomenon so thoroughly gives expression to the climate and the constitution of the soil as the presence of particular plant-communities which prevail, and, accordingly, the determination and description of such communities constitutes an important part of geography. Hitherto, it is true, only a few investigators have paid attention to this subject, and even they have given it but moderate study, the reason being probably that for the determination and description of plant-societies comprehensive data concerning all the species which flourish in the district under investigation are requisite, and the acquisition of such data has been greatly neglected of late years owing to the paramount attractions of other departments of Botany. The small progress of our knowledge in that direction is due also in part to the circumstance that a uniform method of investigating, describing, and classifying plant-communities has not up to the present time been successfully instituted.

The first thing that strikes anyone who takes up this subject is the fact that the different species of plants play very unequal parts in the formation of communities. Certain species predominate in respect of the number of their individuals. They determine the general character of the community, and form the groundwork of the vegetation as a whole, whilst the rest only make their appearance here and there, and look as though they were merely intercalated in the groundwork. It stands to reason that such dominant species, as they are called, belong chiefly to those which by nature grow together in numbers, and that those in particular are the most conspicuous which are aggregated together on a large scale.

Having regard to the dependence of plants upon soil and climate, the nature of which has been fully set forth in the first volume of this work, it might be expected that all plants living under identical conditions would have a common aspect or physiognomy. But this idea is only confirmed in the case of dominant species. The subordinate species may differ from the dominant ones, and also amongst themselves. One of the most usual causes of such differences of form is that the subordinate species of a community pass through the processes of budding, flowering, and fruiting at different seasons relatively, and that one species is adapted to the conditions which prevail in the spring, another to those of summer, and a third to those of autumn. It may also happen that certain reciprocal advantages accrue to neighbouring members of a community from the variety in the forms of their stems, foliage, and flowers. If one species affords at the right moment the shade required by another, or serves as a support for it to climb up, or protects it from high winds, such assistance not only does no harm to the community, but, on the contrary, con-

tributes materially to its preservation; and the same may be said of the cases where a contrast between the colours of the flowers of adjacent species promotes visits from insects, or where any other mutual help is afforded by plants growing side by side in a community. The general aspect of a community is scarcely influenced at all by diversities in the nature of the subordinate species, but depends solely on the dominant species which enter into its composition. These stamp their characteristic aspect upon the entire community, and determine the general impression conveyed to the observer.

This fact is of great moment when we come to the task of identifying, classifying, and naming the various communities formed by plants. Not only must the gregarious dominant species afford the basis of description in the case of each separate community, but their external appearance is the most important means of classifying in groups, according to similarity of aspect, the numerous communities which have been formed in the present period of the earth's history. Observations made under natural conditions, and extending over many years, have led to a division of plant-communities into the following nine groups:—

I. *Forests.*—The dominant species are plants with standard stems (see vol. i. p. 712). In accordance with the common notion of a forest, the stems which constitute its substructure are destitute of branches or leaves up to a certain height. Where this height is not much above that of a man, we speak of a copse; but if the standard stems remain branchless and leafless to a greater height, the assemblage of plants is called a forest proper. We might call these two kinds of forest (for the purposes of this chapter) high forest and low forest, though the terms are not in all ways free from objection; further, the circumstance that high forest has been low forest in the younger stages of its development is an additional reason against their adoption. If the trees of which a wood is composed are so close together that their top leaves and branches are in contact and form a sort of roof, the wood is said to be crowded or dense; whilst, if the trees are so formed and situated relatively to one another as to allow the rays of sunlight to penetrate between them and reach the ground, the wood is said to be thin.

II. *Scrub.*—The dominant species are shrubs, semi-shrubs, and cactiform plants growing in thickets, and never developing standard-stems, but branching from the very base, even when full-grown. The transition is quite gradual from erect scrub, reaching to a height of 2 or 3 metres, to those in which the stems lie upon the ground, and only lift their woody branches a few decimetres above it. It is the nature of shrubs and semi-shrubs to form thickets. Most of the bigger shrubs are impenetrable if not modified by human agency. In special situations, and under certain annually recurring conditions, woody plants of a kind, which usually develop into trees and exhibit standard-stems, may be dwarfed and assume the form of tall shrubs. For example, in the Alps, where trees growing near the boundary-line, beyond which their existence is impossible, are liable to be loaded with heavy masses of snow, and again, in the valleys annually exposed to avalanches, the Beech grows in regular thickets. They are, nevertheless, to be looked upon as forests which have

been dwarfed by peculiar circumstances to the level of low forest. If the uncongenial conditions referred to were to cease, a forest with standard-stems would grow up on the spot.

III. *Plains.*—The dominant plants are perennial and profusely-flowering herbs and undershrubs of gregarious growth. The form, direction of growth, and mode of ramification of the aërial herbaceous stems is always conspicuous, and may even be recognized when the foliage-leaves are of considerable size. Innumerable grades of this form of plant-community exist between Thistles and Umbellifers, reaching a height of 2 metres, which flourish on the Steppes, and the undershrubs scarcely 2 centimetres high, which grow on the débris-slopes in high mountain regions. No sharp line of demarcation can be drawn between them. Nor can any exact distinction be maintained between those Plains in which annuals and biennials and those in which perennial growths predominate. It is, however, possible within certain limits to distinguish between the different types of vegetation under this heading.

IV.—Another type, which may be termed the *frondose* type, has as its dominant plants such as have their stems either entirely subterranean, or else rising but slightly above the ground, whilst from their extremities are developed a crowd of fronds, branch-like leaves, or leaves with large laminæ. The stems are completely hidden by these leafy structures, so that their form and direction and the nature of their ramifications are never clearly visible. This type is conspicuously wanting in flowers. Where flowering-plants also form a constituent part, such plants either have precocious flowers, which have already passed into the fruiting stage by the time the mass of foliage has unfolded, and which subsequently disappear without leaving any trace (e.g. *Saxifraga peltata, Tussilago, Petasites*), or else their flowers are so lost amid the innumerable large foliage-leaves that they do not occasion any material alteration in the general aspect of the plant-community (e.g. *Funkia, Nelumbium*; see fig. 436, p. 775, and most Aroideæ). A special form of this type is exhibited on the surfaces of stagnant or gently flowing water, where discoid foliage-leaves rest upon the water and cover the surface completely. Of it there are several varieties depending on the dimensions of the constituent parts; *cf.*, for instance, Water Lilies and Duckweed.

V. *Ribbon-growths.*—The dominant plants are social hydrophytes with submerged stems and foliage-leaves, or with stem-like or foliaceous thalli. Sometimes forms possessing foliaceous thalli and long, flaccid, ribbon-shaped foliage-leaves predominate, sometimes forms which look like submerged leafy or leafless shrubs, but which differ from real shrubs in that they are herbaceous throughout. A gregarious growth of species with thalli or foliage-leaves which are split up into long narrow segments, or of species whose thalli exhibit a whorled system of ramification may also be present. Ribbon-growths may be separated into various subdivisions, according as one or other of these different sorts of plant predominates.

VI. *Reeds.*—The type is afforded by plants which grow in quantities together and have herbaceous stems of the kind called haulms and scapes. The stems are destitute of foliage-leaves (Horse-tails, Rushes, &c.), or else they bear long, narrow

leaves. Shoots bearing inconspicuous flowers spring up from the species which grow in tussocks, whilst the non-tussock-forming, but more continuously crowded types, develop haulms and scapes bearing an abundance of leaves. The tufted sedges afford an example of the former, and arundinaceous plants of the latter. A reed-like vegetation is developed both on marshy and on dry ground; instances of the latter occur in the Tropics and in Steppe-regions.

VII. *Carpet.*—The typical character is given by low, perennial plants, which form a close mat covering the ground. According as plants with narrow, stiff, grass-like leaves predominate, or such as form a soft, swelling carpet, two types may be distinguished; further, according to the nature of its most important constituents the community may be spoken of as a grass-carpet, herbaceous carpet, moss-carpet, &c. Carpets may grow either on dry or on marshy ground. Sometimes they are restricted to the immediate vicinity of springs or form merely a coating to slabs of rock, but they also spread over wide areas on mountain-slopes and basins. They belong especially to high mountains and to the Arctic regions.

VIII. *Incrustment.*—The dominant species are Thallophytes, which become rigid and brittle when dry or as a consequence of being incrusted with lime. The aggregations of these plants either form solid banks and reefs or else spread in the form of a loose covering over the earth, or they appear as incrustations on rock, earth, or sand. They develop both in the air and under water.

IX. *Felts.*—The dominant species are plants possessing thalli composed of delicate filaments which are more or less entangled together. They may grow in water either in a flocculent form or in coherent felted masses, and they also appear as a thin coating to stones or earth, in which form their characteristic colours render them visible from afar.

The names applied to the above nine classes or types of plant-communities are purposely devoid of reference to the particular alliances, families, or genera concerned in the formation of the communities, because the origin of the latter has nothing to do with the existence of any affinity amongst their constituent plants. Nor has it been possible to take into account the nature of the habitats or the situation of the zones and regions of the earth's surface where the communities grow. This is not the case, however, when we come to name the separate communities which belong to the above classes. For this purpose the use of a name which refers to the habitat, zone, or region where the particular community flourishes, or to the ruling species, genera, or families of which it is composed, is not only inevitable but actually desirable. The most convenient system of nomenclature to adopt here is that which has proved the best in all other descriptive sciences. In accordance therewith each plant-community is designated by two names, one denoting the class to which the community belongs and the other indicating its special characteristics.

In the present state of our knowledge it is impossible to name even approximately the plant-communities which are formed by the aggregation in various ways of some or other of the many thousands of species inhabiting the earth. I

Fig. 481.—Bamboo Forest in Ceylon (from nature by von Königsbrunn).

Fig. 482.—Mangrove Forest in India (from nature by von Ransonnet).

will therefore only make a few observations on the subject, and draw attention to the most striking cases of plant-communities.

The greatest interest naturally attaches to forests which impress the observer by their size, and it is easy to understand why these have always been chosen for the most thorough investigation and description. As regards the species which are either the only constituents of the community, or at any rate its ruling members, we must first distinguish forests of deciduous Conifers and those of evergreen Conifers. A Larch forest (see fig. 354, p. 483) may be taken as an example of the former. Of the evergreen variety there is an extremely large number, owing to the fact that most true Conifers grow in dense forests. A forest of Spruce Firs is represented on p. 415, vol. i., a forest of Silver Firs on p. 717, vol. i., of Scotch Pines on p. 723, vol. ii., and of Arolla Pines on p. 724, vol. ii. Forests composed of Angiosperms are likewise differentiated into deciduous and evergreen. Amongst deciduous forests of this kind the Beech-woods (see p. 761), Birch-woods (see p. 721, vol. i.), and Oak forests (see vol. i. p. 716, fig. 173) of the North Temperate Zone are especially noticeable on account of the characteristic aspect exhibited in each case. Angiospermous evergreen forests manifest their greatest variety in tropical and sub-tropical regions. To the Tropics belong also a number of other special kinds of forest, such as those composed of Euphorbias, Casuarinas, Bamboos (see vol. i. p. 713, fig. 172), of Mangroves (see vol. i. p. 605, fig. 143, and p. 759, fig. 187), and of Palms (see vol. i. Plate VIII. opposite p. 712), respectively. Drawings from nature in the Tropics representing Bamboos and Mangroves are also given in figs. 481 and 482.

Scrubs, which are, so to speak, repetitions of woods or forests in little, may be similarly divided into groups. We distinguish between those in which the shrubs and semi-shrubs, which are predominant or in exclusive possession, are leafless and those where the shrubs are provided with foliage. Amongst the social plants of the first group switch-plants and certain cactiform plants play a prominent part (see vol. i. p. 331, fig. 80, and Plate IV. p. 446). The social plants of the second group are either evergreen or deciduous. The former are furnished with acicular or squamiform leaves which are appressed to the branches (shrubby Conifers and Heaths), or else are clothed with flat, expanded leaves. The case of Alpine Roses (see Plate X.) will serve as an example of the second variety. Amongst deciduous shrubs and semi-shrubs which grow sociably and form extensive scrubs we may mention Tamarisks, Spiræas, Roses, Dwarf-Almonds, Dwarf-Birches, Dwarf-Willows, Proteaceæ, Labiatæ, Broom, and Mimosas.

As regards plains we must first distinguish those where the predominating perennial plants have no foliage-leaves, but are furnished instead with green, fusiform shoots and branches of a foliaceous nature (e.g. *Salicornia*). Of leafy plants which occur as predominant members of plains we may mention Umbellifers, Thistles (see vol. i. p. 436, fig. 115), Agaves and Pine-apples (see vol. i. p. 657, fig. 153), and the Asphodel (see fig. 413, p. 729), as the most striking examples. The rest of the social suffrutices may be placed in three groups. The species

belonging to the first group, to which belong in particular many Composites, Caryophyllaceæ, Chenopodiaceæ, Papilionaceæ, and Cruciferæ, are multifariously branched from the very base (e.g. *Artemisia, Gypsophila, Salsola, Melilotus, Crambe*); the species of the second group have upright stems which are unbranched up to the region of the flowers and bear entire leaves (*e.g.* many species of *Verbascum, Epilobium, Œnothera, Euphorbia*), and the species of the third group possess erect stems which have few branches, or none at all, but bear variously lobed and compound leaves (e.g. *Glycyrrhiza, Eupatorium, Tanacetum, Sambucus Ebulus*).

As regards the fourth or frondose type (*cf.* p. 888), we have already indicated certain varieties. In describing the different communities of this kind special emphasis must be laid also on the circumstance of the green laminæ being entire, as in *Petasites, Tussilago, Nelumbium, Asarum, Scolopendrium,* and *Saxifraga peltata,* or divided and incised, as in most Ferns, several Aroids, and a few Hellebores. We must also take into account whether the fronds or foliage-leaves are deciduous or evergreen, as in *Hedera* and *Helleborus niger.*

Ribbon-plants occur in great variety in both flowing and stagnant waters, be they fresh, brackish, or salt. The general aspect of any particular aggregate of these ribbon-like forms varies according to the area and shape of the foliage or thallus of the species concerned, and particularly according to whether the stems or the stem-like parts of the thallus are lax or packed close together so as to form a dense, pulpy matrix. The most conspicuous examples of social species are *Myriophyllum* with pectinate leaves, the Pond-weeds (*Potamogeton*) and Zannichellias with filiform leaves, the Pond-weeds with broad, translucent leaves (see vol. i. p. 551, fig. 136), the Grass-wracks (*Zostera*), *Vallisneria* (see vol. i. p. 667, fig. 155), and *Cymodocea,* also a few of the Mosses (e.g. *Fontinalis*), various species of *Fucus, Laminaria* (see vol. i. p. 588, fig. 139), *Sargassum, Macrocystis,* and *Cystosira* amongst Brown Seaweeds, species of the genera *Ceramium, Callithamnium, Polysiphonia,* and *Lemanea* amongst Florideæ, the species of *Bryopsis* and *Caulerpa* amongst the Siphoneæ, and the several species of *Chara* and *Nitella* amongst Stoneworts.

The points whereon the classification of Reeds is based have been already indicated on p. 888. A number of distinct forms may be distinguished according as particular species of Horse-tail, Sedge, Rush, Restiaceæ, Scirpus, Calamagrostis, &c., prevail. The drawing of a Papyrus-swamp on p. 747 may be taken as typical of this class of vegetation. In the North Temperate Zone, of those which grow on dry ground the most prevalent species are those of the genus *Calamagrostis.* A great many Reeds occur in the Tropics and in the Steppe regions of both the Old and the New World, especially in the pampas, llanos, &c.

The plants which constitute the dominant members of carpet include both Phanerogams and Cryptogams. Of the former the most important are the interweaving and tussock-forming Grasses, Sedges, and Rushes, the interlacing, grass-leaved Caryophyllaceæ (e.g. *Alsine Rosani, Cherleria sedoides, Silene acaulis*), the species of Houseleek (*Sempervivum*) which form rosettes, the Saxifrages of the *Aizoon* group, the loosely-woven delicate Saxifrages which grow near springs, and

lastly, Montias. Of the Cryptogams almost all are Mosses, the chief species being the Sphagnums, Polytrichums, the species of *Dicranum* and *Gymnostomum* which grow in dense aggregates, and the Hypnums which cling together in loose meshwork (e.g. *Hypnum Schreberi, Hylocomium splendens,* and *Hylocomium triquetrum*).

Only Lichens, Florideæ, and a few Stoneworts take part in the formation of incrustments. Extreme variety is exhibited by Lichens which combine to form crusts closely appressed to the substratum. The chief dominant plants are various species of *Acarospora, Amphiloma, Lecanora, Lecidella, Pertusaria,* and *Verrucaria.* The best-known and most widely-distributed incrustment is that which is formed by *Lecidea geographica* or *Rhizocarpon geographicum,* and imparts a characteristic colour to the blocks of stone on slaty mountains. A looser type of incrustment is composed of various fruticose Lichens, principally of Cladonias and Cetrarias, and are most striking in high mountains and in the Arctic tundra. A less important form is one composed of submerged Characeæ and Florideæ incrusted with lime, *e.g.* by species of *Corallina.* The lime-incrusted species of *Lithothamnium* and *Lithophyllum* which combine to form solid bank-like incrustations known as nullipore-banks only occur in the sea.

Felts are formed by filamentous Algæ. The dominant plants are Scytonemaceæ, Conjugatæ, Ulotrichaceæ, Œdogoniaceæ, Vaucheriaceæ, and a few others. The Conjugatæ, such as the various species of the genus *Spirogyra,* fill stagnant ponds with their green filaments; several of the Vaucheriaceæ grow in closely felted masses in water-courses or on damp earth, and several Scytonemaceæ and Confervoideæ weave themselves into thin mantles over stones. Felts are but seldom of very conspicuous appearance. The best known is the thin felt formed by *Trentepohlia Iolithus,* to which is due the red coloration of blocks of stone ("Violet-stone") seen in mountain regions.

It is only in rare cases that a plant-community is composed of a single species alone. For the most part two, three, or even more species of similar aspect are jointly predominant. At the same time it may happen that at one spot one species, at another spot another species is kept in check without any material alteration being thereby incurred in the general appearance of the particular community. Thus, for instance, the slopes of the schistose mountains of the Central Alps are clothed with carpets in which *Carex curvula, Juncus trifidus,* and *Oreochloa disticha* are dominant species. Here and there these three species share equally in the composition of the carpet, but in many places one is paramount, whilst the others sink into the background, so as to be scarcely noticeable at first sight. No further explanation is requisite to show that in such cases the community must not be named after one only of the dominant species.

As regards the subordinate species of a community it would be a great mistake to suppose that their occurrence is subject to no sort of rule. Though they seldom have any striking influence on the *tout ensemble* of the community their importance in it must not be under-estimated. Many of them are so constantly associated with

certain gregarious species that, where a plant of the one kind occurs, the presence of its companion species of the other kind may be inferred with certainty, and obviously due regard must be paid to such constant companions in any description of particular communities. A further circumstance which must not be overlooked is that up to a certain point the subordinate species may replace one another. Thus, for instance, that variety of carpet in which the Mat-grass (*Nardus stricta*) forms the dominant species, includes as subordinate species both in the Alps and the Carpathians *Homogyne alpina, Hieracium alpinum, Campanula Scheuchzeri*, &c. Certain other subordinate species, e.g. *Potentilla aurea, Hypochœris Helvetica* and *Campanula barbata*, which are almost invariably present in the community in question when it grows in the Alps, are, however, replaced in the Eastern Carpathians by *Potentilla chrysocraspeda, Scorzonera rosea*, and *Campanula abietina*.

Special attention must be drawn to the fact that species which are gregarious in one plant-community occur as a mere sprinkling in another. When this observation is first made in Nature it is apt to lead one to suppose that it is a vain task to attempt to arrange the different communities in groups, and to define and describe each separate kind. But more careful study soon convinces one that the phenomenon in question, far from interfering with the scientific treatment of the subject, actually assists it, and that the history of plant-communities is elucidated thereby. It has been repeatedly remarked that mud newly deposited by water, exposed soil, and naked rock do not forthwith deck themselves in their permanent mantle of vegetation, but that first of all small Algæ, Lichens, Mosses, and various annual Phanerogams establish themselves and prepare the way in the course of time for other plants. This preparation, which was described in vol. i. pp. 257–268, consists not only in mechanical changes in the ground, but also in the admixture of humus derived from the parts of the first settlers which die off. The only species which take possession of ground so modified are such as differ entirely from the first colonists, and, curious to relate, the latter are gradually ousted by the new arrivals and driven from the field. But the second settlement has no permanence either. The quantity of humus arising from the death of plants increases from year to year, the soil becomes too rich for the plants in possession, and the process of eviction is now undergone by them at the hands of fresh species, which thrive on the rich soil, and gradually possess themselves of it. At least three successive series of settlers may thus be traced on every spot, and not infrequently the number is four or five. Now, if each of these groups corresponds to a particular community, which is as a matter of fact the case, the phenomenon described must produce the same impression as though the communities became transformed into one another in course of time. It is therefore necessary to recognize the existence of the incipient and decadent stages as well as that of predominance. In the incipient stage relics of the community which previously occupied the same spot are still to be found, and in the stage of decadence the first pioneers of the community that is to succeed make their appearance. When, for example, a carpet is invaded here and there by individual plants belonging to species indicative of communities which pertain to some other type,

such as scrub or plain, the occurrence does not in the least confuse the definition and description of the carpet. It only shows that for purposes of determination and description, whilst attending primarily to the stage of the community when development has reached its zenith, we must also take into account in each case the stages of incipience and decadence, and the relations to other communities.

Wherever the configuration and composition of the ground favour the formation of various kinds of habitat within narrow limits of space, there the particular plant-communities which correspond to those habitats develop in great variety close together. The boundary-lines of adjacent communities are disposed in a multitude of different ways in such cases. In lowlands where gentle hills alternate with shallow depressions, and where from sand one passes to clay, and thence, perhaps, to ground covered with saline efflorescence, the communities are not infrequently pieced together like the components of a mosaic. In other places those which cover a small area are interspersed like islands in the midst of the more extensive communities; and, again, in other cases the different areas are in the form of contiguous strips and zones. The last mode of distribution occurs chiefly along the margins of still or running water, and is explained by the uniform diminution of moisture in the ground as the distance from the water's edge increases, and in the case of still water also by the tendency of plants to advance from the margins towards the middle of the expanse of water where they grow, or, in other words, from the continuous transformation of the ribbon types which flourish in water into reeds, of reeds into plains, and of plains into carpets or into forests.

It very often happens that two or more plant-communities are intermingled, and that the whole exhibits a kind of stratification. A pine forest may exist by itself, that is to say, it may include nothing but dominant pines with, perhaps, a sprinkling of a few other kinds of tree, and the ground may be bare except for a bed of dry fallen needles. On the other hand, a carpet may have developed on the forest floor, whilst, in addition, a Bilberry scrub, a low scrub of *Calluna vulgaris* or *Erica carnea*, and a high scrub of Juniper may have obtained a footing, all of which communities are capable of existing independently without the shelter of the pines, and are often met with thus alone. But although the presence of the one community is not indispensable to the existence of the other, the fact of their occurring together shows that no injury is suffered on either side in consequence of the companionship, and it is much more likely that communities growing on the same ground are mutually helpful and protective. In many cases there is no doubt of this, as, for example, when a community of tall plants develops on soil previously prepared by a community of low plants without completely ousting them. We gather, then, that the conjunction of several communities is by no means fortuitous, that the association is always between certain particular communities, and that even here we find strict orderliness and subjection to definite laws.

Unions of communities formed in the manner above described have been termed *plant-formations*, probably from analogy with the combinations of strata of earth and stone which geologists call formations. The selection of this name is not quite

fortunate, but having been once introduced into the science, it must remain, and it is only necessary to point out that the communities united in a formation do not always exhibit any obvious stratification. Thus, for instance, in many tropical forests (see fig. 420, p. 741) communities are interpolated which belong to the most widely different types, and exhibit all possible grades in respect of the height to which their component plants grow. These communities occupy sometimes only a restricted area, sometimes a considerable expanse either down on the ground or midway between the ground and the tops of the trees; and, moreover, in all such formations there is always a sprinkling of climbing-plants and epiphytes, which make it quite impossible to discover distinct strata. In many other cases, it is true, the communities constituting a formation are in obvious strata. If we may compare the plant-formation to a building, the communities may be said to form the stories rising one above the other. Sometimes only two communities are superimposed on one another, sometimes it is possible to distinguish three or more strata or stories. There are formations in which each story belongs to a different class of community, but others exist also where two or three of the stories are of the same class, as, for instance, where several scrubs rise one above another, or where two forests are united, so that the crown of one species of tree forms an upper tier, and that of another species a lower tier.

The names of the different plant-formations should be chosen with regard to the community which forms the roof of the entire edifice of plants in each case, and which, therefore, projects above, and, in a sense, prevails over all the other communities.

At the beginning of this chapter stress was laid on the fact that every region receives a characteristic impress from the nature of the plant-communities inhabiting it, and that a knowledge of the latter is consequently of great importance in descriptive geography. The remark has also been made more than once that the particular conditions of soil and climate in a locality find expression in plant-communities, as it must be presumed that the species characteristic of each community can only grow in masses at places where the composition of the soil and the conditions of illumination, temperature, and humidity are in harmony with the specific organization as a whole. But if the local conditions of the ground and climate are reflected in the plant-communities, it is equally the case that the distribution of the plant-communities and formations constitutes an important and perhaps the only available basis for a division of the earth into natural floral areas. We proceed on the principle that every district possessing a series of plant-communities which are peculiar to itself is to be treated as a floral area, and that a limit to such area occurs at every place where the characteristic communities of a particular floral area are threatened with destruction, and, therefore, encounter the natural boundary of their range, where other communities better adapted to the altered external conditions make their appearance, and where there is consequently a change in the aspect of the whole landscape. This also supplies the scheme for a scientific geography of plants. Unfortunately we are still far from possessing any such science. We have only a

scanty knowledge of the plant-communities of Central and Northern Europe, and in many extensive tracts as good as nothing is known concerning the most important of all the data required for a demarcation of floral areas. There is nothing for it, therefore, for the present but to grope along with the help of the little that has been ascertained, and in the case of many districts to retain the demarcations laid down by earlier investigators, notwithstanding the fact that they are based upon altogether different foundations.

According to this system, the various Floras may be roughly distinguished as follows:—

1. **Arctic Flora.** The northern parts of Europe, Asia, and North America, extending southwards about as far as to the Arctic Circle.
2. **Baltic Flora.** Scandinavia, Great Britain, North-German Lowlands, Western Russia encroaching to the south on the Floras of the Mediterranean and Black Sea.
3. **Flora of the Black Sea.** South-eastern Europe, Asia Minor with the exception of its southern and western shores, the Caucasus, Kurdestan, Persia: environs of the Caspian Sea.
4. **Mediterranean Flora.** Shores of the Mediterranean: Southern Europe, the western and southern shores of Asia Minor. Coasts of Syria, Egypt, Tunis, and Algiers.
5. **Atlantic Flora.** Azores, Canary Islands, western shores of the Spanish Peninsula, Morocco.
6. **Siberian Flora.** The plain extending from the river Obi and its sources to the Stanovoi Mountains.
7. **Kamschatkan Flora.** North-east Asia as far south as the region of the Amur River.
8. **Amur Flora.** Amur district, Manchuria.
9. **Chinese Flora.** China, Japan, extending nearly as far south as the Tropic of Cancer.
10. **Flora of Central Asia.** Mongolia, Thibet, bounded to the west by the Steppe-region of the Sea of Aral, and to the south by the Hindu Kush and the Himalaya.
11. **Flora of South Arabia and Mesopotamia.** Northern shores of Somali, South Arabia, Mesopotamia; shores of the Persian Gulf.
12. **Sahara Flora.** The Sahara to about 15° N. Lat., Northern Arabia.
13. **Soudanese Flora.** Bounded on the north by the Sahara, on the south by 10° N. Lat., to the east by the mountainous region of Abyssinia.
14. **Flora of Guinea.** From 10° N. Lat. to 10° S. Lat., eastwards to 35° E. Long.
15. **Zambesi Flora.** From 10° S. Lat. to the Orange River on the south, and bounded to the east by the Drakenberg Mountains and Lake Nyassa.
16. **Abyssinian Flora.** Abyssinia and the mountains adjoining it on the south.
17. **East African Flora.** From the shores of the Indian Ocean to the East African Mountains, northwards as far as 8° N. Lat.
18. **The Cape Flora.** The south-western part of the Cape, bounded to the north by the Great Karroo Desert.
19. **Madagascan Flora.** Madagascar.
20. **Indian Flora.** Bounded to the west by the Indus, to the north by the Himalaya and the Yunnan mountains, and extending eastward as far as the Straits of Lomboc and Macassar.
21. **Pacific Flora.** Pacific Islands from the Moluccas to the Marquesas Islands on the one hand, and from the Sandwich Islands to New Zealand on the other.
22. **Tasmanian Flora.** Victoria, Tasmania, New South Wales, and adjoining regions.
23. **Australian Flora.** Interior and Western Australia.
24. **Canadian Flora.** Bounded to the north by the Arctic Flora, and reaching westward as far as the Rocky Mountains, and southward as far as the North American Lakes.
25. **Columbian Flora.** Bounded on the north by the Arctic Flora, on the east by the Rocky Mountains, on the south by 50° N. Lat.
26. **Mississippi Flora.** Extending northward to the Lake region, southward to Florida, exclusive of the southern third of that Peninsula, and bounded to the west by 95° W. Long.

27. **Missouri Flora.** Region of the Missouri River and of the high land between the Rocky Mountains and the Cascade Mountains.
28. **Flora of the Pacific Slope.** Coast region west of the Cascade Mountains, California.
29. **Texas Flora.** Arizona, Texas, North Mexico.
30. **Mexican Flora.** Mexico as far as Nicaragua.
31. **Antilles Flora.** The Antilles and the Bahamas, southern extremity of Florida.
32. **Brazilian Flora.** Bounded to the west bv the Andes from the Gulf of Guayaquil to Tucuman, extending southward to 30° S. Lat.
33. **South American Flora.** Coast land west of the Andes and the part of South America between 30° and 50° S. Lat.
34. **Magellan Flora.** The extremity of S. America from 50° S. Lat., excluding the high mountains.
35. **Antarctic Flora.** Antarctic Islands, high mountains of the southern extremity of South America.

In this outline only a passing reference has been made to the Floras which at present occupy the higher regions of mountain chains, and which are restricted to comparatively small areas. Yet there is often far more difference between these and the Floras of the lower parts of the mountains and of the adjacent plains than there is between Floras which exist side by side in the lowlands, and are usually scattered over wide areas. Thus, for example, the Flora of the high mountains of Central Europe, commonly known as the Alpine Flora, differs so utterly from the Baltic Flora developed to the north of the Alps, and from the Mediterranean Flora flourishing to the south on the shores of the Mediterranean Sea, that it could not be classed either with the one or with the other. The same phenomenon is observed in other regions where lofty mountains occur, and, probably in addition to the thirty-five Floras above mentioned, as many more high-mountain Floras might be distinguished. The importance of these mountain Floras in relation to the formation of the Floras of the plains and to the general history of the plant-world will be set forth in the next section.

5 THE EXTINCTION OF SPECIES.

In the portion of this work which dealt with the origin of species, the view was taken that the new species which make their appearance in the course of ages are the products of cross-breeding between previously existent species. Valuable support is given to this opinion by facts relating to such genera as are represented in one district by a large number of species, and in another by a single species only. In many cases the wealth of forms comprised by a genus is prodigious. It is no easy matter to bring the numerous species of such a genus under review in a single series, because they are connected not only lineally, but also collaterally amongst themselves in all sorts of ways by intermediate forms. Within these generic spheres new forms continue to spring up in our time, and these are proved to be the results of crossings. For example, the multiplicity of forms included in the Bramble-genus (*Rubus*) is extremely great in Central Europe.

Botanists of the old school supposed the reason of this to be that the species of *Rubus* vary from some unknown cause—presumably from an intrinsic tendency in themselves. At the present day no intelligent observer doubts that many of the plants thus set down as the results of mere spontaneous variation are species which arose by inter-crossing in comparatively early times. Such inter-crossing was rendered possible by the fact that in the course of those displacements and alterations affecting floras, to which the present distribution of plants must be attributed, several species of *Rubus*, which had survived from previous periods, met and settled down together in Central Europe. On the coasts of Dalmatia and Greece, where only a single species, viz., *Rubus ulmifolius*, Schott (= *R. amœnus*, Portenschlag), established itself when the changes in question took place, there was no possibility of any multiplication of forms. From that solitary species sprang descendants which never changed; in other words, the specific marks of *Rubus ulmifolius* remained permanent in the above-mentioned parts of the Mediterranean floral area. The idea of the old school of Botanists was that this particular species of *Rubus* had no inclination to evolve new species; or, to use the more erudite but still less intelligible mode of expression, it was destitute of any tendency towards differentiation. The proper explanation of the fact is, however, much simpler and more natural. In the region where this particular species of *Rubus* is settled, there is no possibility of new species of that genus arising by means of inter-crossing. Perhaps some future displacements of floras will bring *Rubus ulmifolius* into proximity with other species of Bramble, and in that case it is sure to take part once more in the generation of new species. If, on the other hand, some event should cause the extermination of the entire Bramble-flora in the adjacent districts, and *Rubus ulmifolius* should remain isolated, no new species will spring from it any more than hitherto. A completely isolated species may continue to reproduce and multiply sexually and asexually for centuries without exhibiting any alteration, provided that the conditions of climate and soil are congenial to it, but it cannot take any part in the production of new species. If at length destruction befall such a species—a by no means impossible contingency, as one change of climate succeeds another, and causes fresh displacements of the limits of plant distribution—the event would connote the extinction of the whole genus of which this species was the sole surviving representative.

The result of comparative researches has been to show that the extinction of single species frequently occurs, whereas such groups of species as Botanists designate by the name of genera rarely die out. By far the greater proportion of the plants whose remains have been preserved from former periods in a fossil condition belong to genera which are represented by plants still living at the present day; only many of the extant representatives differ specifically from those which existed long ago. We conclude that the living types replace extinct ones and have entered upon their parts in life. It is also worthy of note that the fossil remains are often found at entirely different places from those inhabited by their nearest relatives in modern times.

The most striking examples of genera that have become extinct are afforded by the alliances to which the Club-moss and the Horse-tail respectively belong (see pp. 713 and 716). Those genera most exposed to the danger of extinction are such as are only represented by a single species (termed *monotypic* genera). This risk is intensified if the species in question only occurs in one district, as is the case, for instance, with *Welwitschia.* The genus *Rhodothamnus* of which only one species, *R. Chamæcistus,* lives at the present day, and the genus *Azalea* which is, so far as we know, represented by the species *A. procumbens* (*Loiseleuria procumbens*) alone should, on the other hand, have a better chance of escaping extinction. For the area of distribution of the former is broken into two sub-areas by the broad stretch of land reaching from the Eastern Alps to the Altai Mountains, whilst the *Azalea* grows not only on the high mountains of Central and Southern Europe but also in the Arctic regions, leaving a great space between the two areas uninhabited by its kind. Thus, presumably, even if such a species were to vanish entirely from one of its sub-areas of distribution in consequence of changes in climatic conditions it would still be represented by individuals growing at some spot which, being remote from that sub-area, would in all probability not have been affected by the alterations in question.

The number of species that have died out is extremely large. Every group of species which comprises both living and fossil members affords instructive examples in this connection. It is assumed that of species now living the endemic kinds have their existence most seriously menaced, or, in other words, are exposed to the most speedy extinction. If the restricted areas of the South-eastern Alps, where *Wulfenia Carinthiaca,* the most famous of the endemic species, is native, were to undergo a change of climate which no longer permitted the propagation of that species either by sexual or asexual methods, and at the same time rendered its migration impossible, it would be only a matter of time before *Wulfenia Carinthiaca* disappeared completely from the face of the earth. The genus *Wulfenia* would not, it is true, thereby become extinct, for a second species named *Wulfenia Amherstia* occurs in the Himalaya. But as this species, too, is endemic it might easily be overtaken by the same fate, and then the entire genus would have died out. It is, however, conceivable that the change of climate supposed to affect the South-eastern Alps, instead of causing the extinction of *Wulfenia Carinthiaca,* might result in the expansion of its area of distribution, and that no such hindrances to its migration as at present prevail should exist. The two species now inhabiting such widely remote districts might then conceivably come together and cross with one another, with the result that new species would be produced in the genus *Wulfenia.* It will be seen from these examples that one cannot be too cautious in dealing with assumptions concerning the future destinies of species. Many endemic species are probably doomed to extinction in the near future; but it is also not impossible that they may instead be called upon to play an important part in days to come.

An account has already been given (pp. 590, 592) of the manner in which nature affords compensation for the extinction of species, and how new species, the

products of crossing, take the place of the parent-stocks, so that the only remark that need be added here is that when such substitution is observed in the case of plants belonging to successive geological periods, it seemed as though a gradual re-casting or moulding of the species had taken place, and was regarded as a phenomenon determined by the direct effects of variations of climate until the time when the great importance of crossing in relation to the genesis of new species began to be recognized.

The partial extinction of a species, *i.e.* its disappearance from particular parts of its area of distribution, must be distinguished from complete extinction. Of the numerous instances of partial extinction within our knowledge some have been due to intentional or unintentional extermination by mankind, but the majority are cases where purely local extinction has resulted from natural causes independently of human influence. Reference has repeatedly been made in these pages to cases of plants which grow in the midst of now reigning floras and yet do not belong to them, and they have been likened to outposts left behind by former occupants of the soil, being apparently the remains of floras which formerly flourished on the areas in question, but which have been turned out and forced to take refuge in neighbouring regions. If their displacement were due to climatic vicissitudes it is conceivable that separate species or even entire communities may have been left behind here and there in especially favourable, though possibly very restricted habitats, and such isolated spots then seem as though they had been wrested from the main area of distribution which stretches over a wide expanse of country in the vicinity. Interesting examples of this are afforded by several species which are confined to isolated habitats in Carniola, of which the "Königsblume" (*Daphne Blagayana*) may be selected as a type. This plant grows on the slopes of some mountains in the neighbourhood of Laibach. Before the flora of the Balkan Peninsula had been accurately explored it was believed that this species of *Daphne* had no other habitat than that on the mountains above mentioned. More recent botanical researches have, however, revealed the fact that the main area of distribution of *Daphne Blagayana* is really in the Balkan Peninsula, in Bosnia and Servia, and that the habitat in Carniola is to that area as an island to the mainland. When one sees by what a small number of individuals, amounting to some thousands only, this curious plant is represented in Carniola, and how rare it is for even these to bring fruits to maturity owing to the fact that autogamy is impeded and that the supply of insect-visitors is insufficient, there is no escape from the conviction that a series of very severe winters would be enough to cause its complete extermination in this district. Under such circumstances its existence in the main area of distribution in the Balkan Peninsula might not be in any way imperilled, for it is not likely that the particular causes to which the extinction of the species in the small area in Carniola would be due would operate in all the habitats in the larger area, which is hundreds of kilometres away.

That such phenomena as have here been suggested as possible and even probable in the case of *Daphne Blagayana* do actually happen is evidenced by the plant-

species which in one district form a considerable part of the flora in possession at the present day, whilst in another floral area they are only found in the fossil state and under conditions which leave no doubt that they formerly lived there, but have long died out. *Rhododendron Ponticum,* for example, is an important constituent of the flora which now flourishes in the neighbourhood of the Black Sea, and is also found far to the west in an unrestricted area in the South of Spain at a great distance from the main area of distribution. It is encountered in the fossil state on the southern slopes of the Solstein chain in Tyrol in the upper strata of the so-called Höttinger Breccia. Thus this plant must have ranged formerly through Southern and Central Europe to 47° N. Lat. In the South of Spain it has survived on an isolated spot, whilst in the Northern Dolomites it has died out. A similar instance is offered by the case of several Juglandaceæ which form part of the woods of North America at the present day, and are only found as fossils in Europe.

The results of researches into the history of the separate species constitute the foundation for a history of the entire plant-world. Formerly the discovery of fossil-remains was looked upon as the most important means of eliciting that history, but now the distribution of living plants is taken into account, and the significance of such circumstances as the presence of endemic species and of species isolated in the midst of a foreign flora is fully recognized. A study of endemic species and of outlying sub-areas of distribution yields in particular most valuable information concerning the conditions which prevailed in the earliest periods of the earth's history. The most noteworthy inference made in this connection is that over a great part of central Europe since the last ice-age a flora was evolved which was only capable of existing under the influence of a continental climate of far greater warmth than now prevails. For instance, plants whose main areas of distribution at the present day are in the steppes of Southern Russia, in the Crimea, and in the valleys of the Caucasus are found growing, sometimes alone sometimes in communities, in Central Europe, in the region of the Baltic Flora, on warm, sunny mountain-slopes, and in sequestered glens far from the modern lines of traffic, and under circumstances which exclude all possibility of an immigration having taken place in recent times. Such exceptional habitats of the plants in question occur on hot, sombre rocks of serpentine in Lower Austria, on terraces of loess and mountains of schist, situated on the eastern border of the Böhmer Wald and the Mährische Gebirge, in the interior of Bohemia and westwards on scattered spots as far as the Harz Mountains, and, again, in the region of the Northern and Central Alps, from the Wiener Becken to the Lake of Constance, as, for example, far away in the highest parts of the valleys of the Adige and the Inn. These plants may be for the most part described as Steppe-plants, and if, as can no longer be doubted, they are the remains of a flora which once ranged in Central Europe as far as the Harz Mountains, we may conclude that just before the establishment of the present climatic conditions which suit the Baltic Flora, a Steppe-climate prevailed over the area referred to, and the summer was hot and dry. There is good ground for supposing that the various animals belonging to the Steppe-fauna (Steppe-antelope, Steppe-marmot,

&c., *cf.* p. 462) which have been discovered in Central Germany are relics of this period, that they lived with the Steppe-plants and withdrew eastward at the same time in consequence of the change of climate. It is difficult to say when these changes took place in Central Europe, but this much is certain, that the Steppe-climate prevailed for an exceedingly long time, that the alteration of that climate into the kind which now prevails took place quite gradually, and that accordingly the migration of the Steppe-flora and fauna into the region now occupied by them was performed very slowly.

As the very thing which is injurious to the members of one flora is usually beneficial to those of a neighbouring flora the migrations of plants really take the form of displacements of the boundaries of distribution. No sooner do the species of one flora withdraw to escape a climate that has become unsuitable to them than their place is taken by those members of the neighbouring flora which are adapted to the new climate. In the case above referred to, an immigration of such members of the Baltic flora as prefer a comparatively cool, moist summer would inevitably take place synchronously with the retreat of the Steppe-plants. As regards the situation of the previous home of these Baltic plants there can be no doubt. They came from adjacent regions where the climatic conditions congenial to them already existed, that is to say, from parts then forming the coast and from those mountains which had not been ascended by the Steppe-flora. In advancing inland from the coast and descending from the mountains these plants were only in a measure retracing their steps to places where they formerly occupied the ground, and from which they had been ousted by the Steppe-plants. In other words, before the reign of the Steppe-flora of the Black Sea was established in the valleys and lowlands of Central Europe another flora lived there which closely resembled that which we now call the Baltic flora. No approximate estimate can be given of the length of time, previous to the immigration of Steppe-plants, during which the Baltic flora was in possession of the tract of country thus destined to fall a second time under its dominion; but it has been established beyond question that it was not as yet upon the scene at the period of the greatest prevalence of glaciers in Central Europe, and that its first immigration cannot have taken place until after the retreat of the large glaciers.

At the epoch when glaciers attained their maximum dimensions the places now covered by the forests of Pines and Firs, which are so characteristic of the Baltic flora, and by vast scrubs of heaths and broom, were occupied by low Alpine plants which may for the sake of brevity be spoken of collectively as an Alpine Flora. Formerly botanists were of opinion that this wonderful flora spread southwards like a flowing stream from the Arctic Regions at the epoch in question. This view is not, however, in harmony with more recent discoveries. It was based on the erroneous assumption that the flora of the Arctic Regions was the same as that of the alpine regions of Central and Southern Europe. When we compare the Arctic and the Alpine floras merely by means of their records in books and herbaria, it does indeed look as if the closest relationship existed between the two: for a not inconsiderable

number of species belong to both floras, and are only lacking at the present day in the broad tract interposed between the Alps and the Arctic Regions. But of these species common to both floras the majority are distinguished in the Alps by their rarity, and only grow on particular spots here and there on black earth or peat, or close to cold springs. Many must be the botanists who have rambled year after year over the Alps collecting flowers without ever coming across such species as *Saxifraga cernua, Betula nana, Juncus arcticus,* and *Juncus castaneus,* which are common in arctic areas of vegetation but very rare in the Alps, though they may have climbed all the summits high and low, and searched the most sequestered valleys, and, moreover, may possess a thorough knowledge of Alpine vegetation. Similarly, when a Botanist, who has acquired on the spot an accurate knowledge of the Arctic Flora, pays his first visit to the Alps an entirely new world meets his gaze. Not only is the number of species indigenous to alpine regions much larger than that found in the extreme north, but the two floras differ widely in their composition. The very species which are of most common occurrence in the Alps, and which constitute the ground-work of the communities characteristic of that region, are alien to the Arctic Flora. Such are the extensive meadows of Grasses and Sedges, the low-growing forests of Mountain Pines, Alders, and Dwarf Medlars, the scrub of Alpine Roses (Rhododendrons), and the carpet of prostrate woody plants (*Rhamnus pumila, Daphne striata, Salix retusa, S. Jacquiniana*), besides many other species which are peculiarly adapted to a substratum of rock or débris, and constitute one of the chief glories of the Alps. To this category we must also add the particular plants which, next to the Alpine Roses, are the most commonly recognized representatives of the Alpine flora, viz. *Valeriana celtica, Meum Mutellina, Primula Auricula, Artemisia Mutellina, Gnaphalium Leontopodium* (the Edelweiss). The alpine species of more than 50 genera do not grow at all in the arctic regions, and in the case of many other genera, though both districts possess a few of the species in common, it is just those which are peculiarly characteristic of the Alpine Flora that one seeks for in vain in the extreme north. It would thus be absurd to suppose that such a flora has migrated from the arctic regions to the Alps, and there is much more reason for concluding that the scanty flora of the arctic region was in part derived from the high mountain areas of more southern latitudes.

Researches into the subject of the distribution of Alpine species and of the genera to which they belong have revealed the fact that some alpine plants occur also in the higher parts of the Carpathians, in the Caucasus, in the Altai Mountains, and even in the Himalayas, whilst others are found in the Abruzzi and the Balkans, and upon these data might be based the hypothesis that the alpine flora was derived from the east and south, and migrated in the Diluvial Period from the Himalayas, the Caucasus or the Abruzzi to the Eastern Alps. But the same facts might equally well lead any one who made a similar investigation of the Alpine flora of the Caucasus or the Himalayas to infer that the plants in question had travelled thither from the Alps. I believe that all such hypotheses involve one in a circle, and bring one no nearer to the goal. If we wish to solve the question as to what was the place of origin of

the plants which took possession of the ground whence glaciers and snow-fields retreated after the great diluvial ice-age, it is not necessary to look so far afield. We need only bear in mind that in the period preceding that in which the glaciers attained their maximum size in the higher mountains of the Alps, a flora must have existed there, and that this flora would have been forced down from the higher to the lower parts of the mountains and into the sub-alpine regions by the climatic vicissitudes which occasioned the glacial condition. In the Tertiary Period the diminution of temperature accompanying an increase of elevation was doubtless not materially different from what it is at the present day. The general relief of the Alps was the same in the Miocene period as it is now; also in the Eocene period, and even in the more recent portions of the Cretaceous period the Alps were already a considerable mountain region including probably some high peaks. The Limestone Alps had their fjords, and the Central Alps were deeply cut into by cross valleys. The vegetation clothing the lower slopes could not be the same as that of the higher regions, but, as at the present day, there must have been several floras situated one above the other. Glaciers must have existed in a latitude of from 46° to 48° at an elevation of 3000 metres in the highest depressions in the mountains, and that at so small a distance as 50 kilometres from the sea-coast, and subject to a yearly variation in temperature of 8°–10° Centigrade; and even though woods of Laurels and Myrtles flourished in the latter part of the Miocene period of South-eastern Europe on the spurs of the Alps on the margin of the Wiener Becken, that does not exclude the possibility of an Alpine flora having developed simultaneously on the snow mountains of that neighbourhood, and on the Rax-alp and the Hochschwab (in the mountains of Northern Styria). The Carniola Schneeberg to the north of the Gulf of Fiume affords quite sufficient proof that even a mountain of only 1800 metres may harbour Laurels and Evergreen Oaks at its feet, whilst alpine vegetation flourishes on its summits.

The fossil remains of the Miocene flora that are known to us were all discovered in lowland places, and they therefore only represent the plants belonging to gently undulating ground or growing on quite low mountains, and no inferences can be drawn from them as to the nature of the vegetation of the higher regions. I think that we may fairly deduce the conclusion that the majority of the alpine species lived on the heights of the Alps as long ago as in the Miocene period, and that the Alpine Flora though repeatedly forced down to lower levels, always returned again. As a matter of course the composition of the Alpine Flora underwent many changes in the process. The partial intermixture of species belonging to adjacent floras with the alpine species, which must inevitably have taken place in the course of these displacements, led to inter-crossing and consequently to the production of new species, whereof a proportion were no doubt adapted to the altered climatic conditions and capable of preserving their existence. On the other hand, many of the species which already inhabited the Alps in the Miocene Period have died out there or have only survived at isolated spots of limited area, as, for instance, *Wulfenia Carinthiaca* (see p. 882) in Carinthia, and *Rhizobotrya alpina* on the

Fassa Alps in Tyrol. This holds especially in the case of the majority of those species which belong both to the present Arctic Flora and to the present Alpine Flora. Let us suppose the Alpine Flora driven as far as the North of Germany at the time of the greatest distribution of the diluvial glaciers. Extensive glaciers had also advanced far to the south from the north, and had caused a displacement of the flora indigenous to the Scandinavian Mountains in the Tertiary period as far to the south as Northern Germany. Thus the floras of the north and of the Alps must have met there, and when later the climate again became milder a retreat of the immigrants took place on the one side towards the north, on the other side towards the Alps. On this occasion some species which previously did not occur in the Scandinavian Mountains travelled northward, and some hitherto unknown in the Alps travelled into the Alps. To that epoch must be ascribed the introduction into Germany of several Arctic species, e.g. *Alsine stricta, Saxifraga Hirculus, Pedicularis Sceptrum, Statice purpurea, Salix depressa, Betula humilis,* and *Juncus stygius*—which then became dispersed over the low lands lying at the foot of the Alps in Salzburg and Bavaria, though they did not reach the Alpine region, but remained behind on the northern border of the mountain area.

The remarkable relations above referred to as existing between the Alpine flora of the Alps and those of the Carpathians, the Caucasus, the Altai, and the Himalayas, and also those of the Pyrenees, the Abruzzi, the Dinaric Mountains, and the Balkans cannot be explained by what took place in the Diluvial period. It has been ascertained by geologists that the first glaciation of the Alps was not more recent than, but was possibly even prior to, the third stage of the Miocene Period in the south-east of Europe, and that during that epoch there could have been no connection between the high mountain flora of the Alps proper and those of the Carpathians and the Balkans, not to speak of the mountains lying further to the east or south, even though the Alpine flora may have descended to a much lower level on the eastern side. The high mountain floras have hardly met one another either in the direction of east and west, or in that of north and south. If, therefore, in the Alps, after the retreat of the glaciers, other species joined forces with those belonging to the Alpine flora which returned once more to higher regions, these were species belonging rather to hilly lowlands. Many such species are able to endure the alpine climate without being injured, and they are represented even at the present day by large numbers of individual plants both in the lowest parts of the valleys and on the heights of the Alps. Thus *Erica carnea, Globularia cordifolia,* and *Biscutella lævigata* may be traced from the shores of the Adriatic and the banks of Lake Garda, and from the less lofty heights on the border of the Wiener Becken up into the alpine region, and may be looked upon as representatives of the plants which naturalized themselves in that region after the last diluvial ice-age.

If the kinship of the floras growing on the crests and shoulders of the high mountain chains which succeed one another from west to east and from north to south is not explicable from what took place in the Diluvial period, we must go back to an earlier time when either the mountain ranges now separated from one

another were continuous or an intermingling and exchange of species were rendered possible by floral displacements occasioned by vicissitudes of climate. Before the influx of the first Miocene sea through Servia into Hungary and Austria, the Bakonyer Wald were joined to the Southern Limestone Alps; peaks of the height of the Grossglockner lifted their heads where now only low crests surmount the deposits of the Miocene sea, and those lofty peaks were no doubt clothed with an alpine flora. Similarly there was then no lack of high mountains covered with alpine vegetation between the Alps and the Carpathians. Geological information of this character is certainly of great value when it is a question of explaining the close relationships existing between the alpine flora of the Eastern Alps and that of the Carpathians; but the presence of such mountains before the Miocene Period does not suffice to explain the uniformity of the alpine species, the affinity existing between the natural groups to which they belong, and the curious overlapping and interlacing of the boundaries of their areas of distribution on the high mountain ranges which run from west to east and from north to south. There must also have been at that time some impelling cause to account for the intermingling of the floras in question, and for the displacement of their boundaries. The only phenomena which can be presumed to meet the case are alterations of climate of so drastic a nature as to cause a simultaneous descent—and subsequently again a simultaneous return—of the alpine species belonging to the two mountain-chains. These climatic changes must have been the same as those which culminated in the successive formation and advance and subsequent retreat of glaciers in those of the mountains which were lofty enough and of suitable conformation.

In the most widely different strata of our earth's crust, deposits occur which are to all appearance moraine-débris, and are looked upon as glacial deposits by every unbiassed geologist. There is, therefore, good ground for the hypothesis that an alternate advance and retrogression of glaciers has taken place not only in the Diluvial period, but also in the Tertiary period, and generally in all the periods distinguished by geologists. In my opinion the periodical return of a cold, wet climate, manifested in suitable localities by an increase of glaciers, has everywhere and in every age been the cause of migrations, and indirectly of inter-crossing, the formation of new species and the extinction of old ones; and I think that, so far as it goes, it accounts for the displacements, modifications of type, and other changes undergone by the various floras in successive geological periods. Mountains have played an important part in this history. They are able to produce an inexhaustible supply of plants ever ready to colonize less elevated regions down to the plains below, for their slopes are the camping-ground of plants adapted to every kind of climate. When a slight diminution of temperature occurs, the denizens of the lower forest region spread over the plains; a more considerable access of cold impels the plants of the upper forest-region to become the invaders, and so on until it comes to the turn of the vegetation which subsists close to the limit of perpetual snow, where the snow vanishes for only about 50 days each year. And, just as on occasion of a fall in temperature, the plants gradually descend the mountain sides and disperse them-

selves over the lowlands, so also if the temperature rises they are able to retire to the heights again. No more need be said to show that the advance and retreat of vegetation has taken place, and does still take place, *pari passu* with the growth and melting away of glaciers.

Very various notions concerning the cause of the periodical return of an ice-age have prevailed from time to time. Several prominent experts of the present day believe that alterations in the eccentricity of the earth's orbit are the cause of the phenomenon. When the eccentricity increases the earth's surface is considerably cooled, and as the eccentricity diminishes the heat increases. A period of great eccentricity must have begun about 240,000 years before our era and have lasted 16,000 years. Similarly the great eccentricity which existed 850,000 and 2,500,000 years before our era must have brought about repeated glaciation. By others an alteration of the position of the pole is considered to be the cause of the phenomenon in question. Much may no doubt be urged against this explanation, but several phenomena in the plant-world are more easily reconciled with it than with any other. One example of these is the existence of lofty plants with large foliage in the Arctic region during the Miocene, Cretaceous, and Carboniferous periods, as is proved by the discovery of numbers of fossil remains. In the Miocene and Cretaceous periods, Tulip-trees, Magnolias, Limes, Planes, Bread-fruit trees, and Water-lilies flourished in North Greenland, Grinnell Land, Iceland, and Spitzbergen. None of these plants can live there now, for the two following reasons. Firstly, the conditions in respect of solar illumination which obtain there would not permit of their healthy development; and, secondly, there is not sufficient warmth to enable them to grow hardily. Since the most eminent geologists of the day have declared against the idea of the interior of the earth being in a fiery, molten condition it will not do to attribute to that source the high temperature necessary for great Planes, Magnolias, and Bread-fruit trees to flourish in such high latitudes. On the other hand, the presence of large-leaved Angiospermous trees in North Greenland, Grinnell Land, Iceland, and Spitzbergen would be satisfactorily explained if it were assumed that the spot which now forms the North Pole—and with it the whole region now called Arctic—then occupied a different position relatively to the earth's orbit, and consequently received a different amount of light and heat.

As regards the history of plants prior to the Eocene and Cretaceous periods no data are afforded by the investigation of the distribution of living plants, and we are thrown back on the fossil remains derived from those older periods. These are unfortunately comparatively scanty, and they no doubt represent but a small proportion of the species which lived before the Cretaceous period. Two conclusions may, however, clearly be drawn from these remains, viz.: firstly, that no single main division existed at that time which is not still represented at the present day; and, secondly, that some very conspicuous genera of particular groups have died out and been replaced by other genera of the same groups. Specially noticeable in this connection are the tree Club-mosses of the Carboniferous period and the Calamites, species of Horse-tail which must have formed extensive forests in the Carboniferous

periods. The occurrence of these curious Calamites of the Carboniferous period strikes one most when they are found in localities where the ground is now occupied by low herbs, Mosses, and Lichens, and is covered with snow for three-quarters of each year, as is the case in Nova Zembla, Spitzbergen, and Bear Island. In the region of the Alps, too, we encounter spots where this surprising phenomenon is again presented. One of the most remarkable is the upland valley in the Tyrol known as the Gschnitzthal. I have for many years passed the summer months in that valley, and it is there that the greater part of this Natural History of Plants has been written. The house which I occupy stands at an elevation of 1215 metres above the sea-level, and is built upon a diluvial moraine in the middle of the valley. The glaciers which made the moraine have retreated 15 kilometres, and now form the head of the valley. On its débris, dating from the Diluvial period, now grow Firs and Pines, Junipers and Heather, all of which are members of the Baltic Flora Six hundred metres higher up, arboreal growth ceases and the sides and shoulders of the mountains are clothed alternately with extensive Alpine meadows and scrubs of Alpine Rhododendrons and carpets composed of *Azalea procumbens* and of creeping Dwarf Willows. On the Steinacherjoch, one of the neighbouring ridges, at an elevation of 2200 metres above the sea-level, the ground consists of dark fissured slabs of schist, covered with Lichens and Mosses, and here and there overgrown also by Saxifrages and Primulas. If one of these slabs be split open, the inside is found to bear the impress of Calamites and giant Ferns of the Carboniferous period. What an endless series of changes must the vegetation have undergone since the time when groves of Calamites flourished here. Over and over again has the place wherein they now repose been turned into the bed of a sea wherein were constructed the coral reefs which now surmount the dark ancient schist in the form of pale grey dolomitic peaks. Forest after forest of Coniferous or of Angiospermous trees has spread its shade over the spot for a time and then passed away. Huge tracts of ice have filled the entire valley, and upon the débris of the moraines deposited by the glaciers in their progress now rests a carpet of Primulas, Saxifrages, and Gentians.

> "Ebbe und Flut—so wechselt der Tod und das blühende Leben,
> Blumen pflanzet die Zeit auf das vergessene Grab."

GLOSSARY.

Abscission, the natural cutting off of members by means of a layer of separation.

Absciss-layer, a layer of separation. See above.

Acaulescent, stemless, or apparently so.

Accrescent, applied to the parts connected with the flower, as the calyx, &c., which increase in size after flowering.

Acerosæ, Alex. Braun's term for the Coniferæ.

Achene, a dry indehiscent 1-celled 1-seeded fruit.

Achlamydeous, used of flowering plants which have no calyx or corolla.

Acicular, bristle- or needle-shaped.

Acotyledones, old term (De Jussieu) for non-flowering plants.

Acramphibrya, Endlicher's term for Dicotyledons and Gymnosperms, regarded as plants growing both at the apex and at the sides.

Acrobrya, Endlicher's term for plants growing at the apex only.

Acrocarpous, said of Mosses which produce their fruit (sporogonia) at the tips of their shoots.

Acrodromous. See vol. i. p. 633, fig. 150[1].

Actinomorphic, applied to flowers which may be divided vertically into similar halves through two or more planes.

Aculei, slender, rigid prickles, growing from the bark, as in the Rose.

Adhesion, the union of parts normally separate.

Adnate, congenitally united or grown together.

Adventitious buds, buds produced out of their regular order.

Æcidium, in Uredineæ, a cup-like collection of spores which are budded off from the base of the cup.

Æstivation, the folding of the parts of a flower in the bud.

Aggregate fruit, a fruit formed by the crowding together of distinct carpels; the product of a single gynœceum when that gynœceum is apocarpous.

Aggregation, the condition of extreme activity of the stalk-cells of the tentacles of a Drosera-leaf, resulting from mechanical or chemical stimulation.

Akinetes, in Green Algæ, are single cells of the thallus, whose original walls thicken, and which separate from the rest of the thallus; they correspond to the chlamydospores of Fungi.

Alæ, descriptive term applied to the two lateral members or wings of a papilionaceous corolla.

Albumen, any form of nutritive matter stored within the seed and about the embryo.

Albuminous, containing albumen, as in the seeds of grain, Palms, &c.

Aleurone-grains, grains of nitrogenous food-material frequently stored in the reserve-tissues of seeds.

Alga, a chlorophyll-containing member of the Thallophyta; one of the plants, the best known of which are called Sea-weeds.

Alliance, a group of allied families or orders.

Amentaceous, having amenta or catkins; consisting of or resembling a catkin.

Amentum, a catkin. See *Catkin.*

Amœboid movements, constant changes of shape resembling those of the "Proteus animalcule" Amœba.

Amphibious, said of plants such as can live either in the water or in the air.

Amphibrya, Endlicher's term for the Monocotyledons.

Amphicarpium, an archegonium when it persists, after fertilization, as a fruit envelope.

Amphigastria, in Liverworts: certain small scales or leaves on the ventral side of the oophyte generation.

Amphigonium, used sometimes by Kerner as a synonym for archegonium.

Amplexicaul, nearly surrounding or clasping the stem: used of the leaf base in certain cases.

Amylum, starch.

Anaphyte, an old term of the nature-philosophers by which the potential independence of every branch or shoot was indicated.

Anastomose, to inosculate or run into each other; to communicate with each other like arteries and veins.

Anatomy, the intimate structure of plants.

Anatropous, said of that form of ovule in which, although the nucellus is straight, the micropyle is bent down to the point of attachment of the funicle, and in which the body of the ovule is united to the funicle, which latter structure is known as the raphe.

Andrœcium, the collective term for the stamens of a flower.

Androgonidia, the cells which in Volvox give rise to spermatozoids.

Androspores, name given to the particular zoospores which in Œdogonium give rise to miniature plants, termed dwarf-males.

Anemophilous, applied to flowers whose pollen is conveyed by the agency of wind; having flowers fertilized by wind-borne pollen.

Animalcule, a vague term applied to small motile organisms in water.

Anisogametes, sexual cells, which show a differentiation into male and female.

Annulus, (1) in Agarics: the ring which often remains round the stalk (stipe), and was originally attached to the edge of the pileus; the remains of the *velum partiale*; (2) in the Moss-capsule: the ring of cells which brings about the throwing-off of the operculum; (3) in the Fern-sporangium: a conspicuous row of cells running vertically, obliquely, &c., around the sporangium, by the contraction of which dehiscence takes place.

Anophyta, Endlicher's term for the Muscineæ.

Anther, the polliniferous part of a stamen; the sac or cavity in which the pollen is contained.

Antheridium, a male sexual organ, usually producing motile spermatozoids.

Anthocyanin, a purple sap-pigment frequent in foliage and flowers.

Antholysis, literally a "loosened" flower, *i.e.* a flower in which the various parts have become more or less foliacious, and from which inferences can be drawn as to the morphological nature of the component parts.

Anthophyta, Alex. Braun's name for the Phanerogamia.

Anthoxanthin, the yellow pigment of flowers and fruits.

Antipodal cells, a group of three cells at the chalazal end of the embryo-sac of Angiosperms.

Apetalæ, Dicotyledons destitute of a corolla.

Aplanospore, a non-motile asexual reproductive cell of the Green Algæ.

Apocarpous, said when the carpels of a gynœceum are separate.

Apophysis, a swelling under the base of the theca in some Mosses.

Apothecium, the disc-like receptacle of an Ascomycetous Fungus.

Arbor, a tree.

Arbuscula, a little or dwarf tree.

Archegonium, in the higher Cryptogams the flask-shaped female sexual organ with neck and venter, the latter containing an egg-cell, the former canal-cells.

Archesporium, a cell or group of cells from which spore mother-cells are produced.

Archichlamydeæ, a large group of Dicotyledons, including the old groups Polypetalæ and Incompletæ.

Areolated, marked with little areas; divided into small areas by intersecting lines.

Aril, an investment to a seed which arises after fertilization. It is usually succulent.

Arthrospore, a form of spore produced in the Schizomycetcs by the segmentation of the tubes into cells.

Arundinaceous, reed-like.

Ascidiform, like a pitcher; pitcher-shaped.

Ascidium, a pitcher; an appendage somewhat resembling a pitcher. See *Pitcher.*

Ascus, a form of sporangium characteristic of certain Fungi. It is generally tubular and contains eight spores, the ascospores.

Ash, the inorganic residue which is left after a plant has been burned.

Assimilation, as used here, the building of a plant-substance from the nutriment of the environment. Often restricted to the manufacture of carbo-hydrate from carbonic acid and water.

Asyngamic, used of plants which are prevented from intercrossing by the fact of their non-simultaneous periods of flowering. Nearly related species can thus inhabit the same spot without hybrids ever being formed.

"Attire", an archaic term, applied by Grew to the stamens.

Auricle, an ear-shaped appendage.

Autogamy, self-pollination, ultimately self-fertilization.

Autonomous movements, spontaneous; originating from inherent tendency.

Auxospore, the reproductive cell of a Diatom. See vol. ii. p. 626.

Awn, a bristle-like appendage, especially in the glumes of Grasses.

Axis, essentially the stem. The root is also an axis.

Azygospore, term given to the "zygospore" when it is formed parthenogenetically with conjugation.

Bacterium, one of the micro-organisms concerned in putrefaction: a term rather widely applied to any member of the Schizomycetes.

Barbs, the retrorse appendages of bristles, or the teeth on leaf-margins.

Bark, the usually hard outer investment of a perennial stem (or root) which has arisen in connection with a cork-cambium; actually it includes the products of the cork-cambium and whatsoever is external to it.

Basidium, a cell from which spores or conidia are produced by a process of abstriction.

Bast, inner bark; a special tissue: *soft-bast*, the phloem—includes sieve-tubes and other non-hardened phloem-elements; *hard-bast*, the thickened prosenchymatous elements or bast-fibres.

Bastard, a term sometimes given to a hybrid.

Bedeguar, name given to the mossy red galls on the common Wild Rose.

Berry, a fruit the whole pericarp of which is succulent.

Bilabiate, two-lipped.

Bizzaria, a fruit, part Orange, part Citron. See vol. ii. p. 569.

Blendling, a name given to a hybrid arising by the crossing of "races".

Blossom, cf. vol. ii. p. 71.

Brachydodromous, used of leaf-veins. See vol. i. p. 630.

Bract, a leaf subtending a flower.

Bract-scale, the lower member of the duplex scale of the female cone of Pine, Fir, &c.

Break back, a term used by gardeners to convey the idea of reversion. Thus flowers break back or revert to an ancestral type.

Bud, the as yet unexpanded rudiment of a shoot; it comprehends both axial and foliar portions.

Bulb (bulbus), a bud consisting of an abbreviated axis with fleshy scale-leaves in which food-material is stored. Usually subterranean.

Bulbil, a deciduous bud, usually formed on an aërial part of a plant. Occasionally used for a little bulb.

Callus, the healing tissue which closes up the wounds of plants. The same term is given to a mucilaginous substance which arises on the sieve-plates of the sieve-tubes, closing them. The latter is of course quite a different structure, and to distinguish it from the former may be called *callose.*

Calyptra, the hood which is raised up on the sporogonium of a Moss. It is the ruptured upper portion of the archegonium.

Calyx, the outer whorl of the perianth, consisting of sepals.

Cambiform cells, cells resembling cambium cells; thin-walled, tapering cells found in the phloem accompanying the sieve-tubes, companion-cells, and bast-fibres.

Cambium, a layer of tissue formed between the wood and the bark, and consisting partly of nascent wood, partly of nascent bark.

Campylodromous, applied to the manner in which veins are distributed. See vol. i. p. 633, fig. 150 [3].

Campylotropous, used of an ovule or seed in which the nucellus, with its integuments, is bent so that the apex is brought near to the point of attachment.

Canker, a vague term applied to the disease or Fungus which attacks plants and causes slow decay.

Capillitium, the thread-like fibres, often united into a reticulum, which are developed within the spores of Myxomycetes and many Gasteromycetes.

Capitulum, a head or globular cluster of sessile flowers.

Caprification, the custom of hanging branches of the wild Fig in the cultivated trees so as to ensure pollination by means of the gall-insects thus introduced.

Caprificus, the uncultivated male form of the common Fig.

Capsule, a dry, dehiscent fruit.

Carobe di Giude, Turpentine Gall-apple, produced on Pistacia Lentiscus by a Pemphigus.

Carpel, a single-celled ovary or seed-vessel, or a single cell of an ovary or seed-vessel together with what belongs to that cell; it may be regarded as a modified leaf.

Carpium, or **Carp**, the oogonium modified by fertilization, which remains as an envelope around the embryo. Cf. vol. ii. p. 47.

Carpo-asci, the more complex Ascomycetous Fungi —all except the Exoascaceæ.

Carpophylla, the carpels.

Caruncle, a localized outgrowth of the seed-coat; a sort of aril.

Caryophyllaceous, appertaining to the Pink family.

Caryopsis, an indehiscent one-seeded fruit, in which the thin seed-coat adheres to the pericarp, as in all cereal grains.

Catapult-fruits, fruits in which the dispersal of the seeds or fruit-segments is due to the elastic reaction of the resilient peduncles or pedicels.

Catkin, a pendulous inflorescence bearing flowers of one sex only; an amentum.

Caudex, a trunk or unbranched stem.

Caudex columnaris, an erect columnar stem, as in Palm-trees.

Caulescent, having an obvious stem rising above the ground.

Cauline, appertaining to the stem.

Caulis, the stem or stalk.

Caulis herbaceus, a herbaceous stem.

Caulis suffruticosus, a suffruticose stem; the stem of an under-shrub.

Caulome, a stem-structure, or the stem-like portion of a plant.

Cecidium, a gall or hypertrophy on a plant-member, due to the stimulating action of an insect or Fungus.

Cell, the structural unit in the formation of plants; one of the individualized portions of which plants are built up.

Cell-membrane, the cell-wall.

Cell-plate, used here of aggregates of cells in one plane.

Cell-sap, the watery fluid contained in a cell.

Cellular, consisting of cells. Sometimes used of plants which are destitute of vessels.

Cellulose, a carbo-hydrate of which cell-membranes are composed; the essential constituent of cell-walls.

Centrifugal, a term applied to such inflorescences as develop from the centre outwards.

Centripetal, a term applied to such inflorescences as develop from without inwards.

Cephalonion gall, a sac-like gall joined to the leaf by a narrow neck.

Ceratonion gall, a hollow, thick-walled, horn-like gall, belonging to the series of Mantle-galls.

Chalaza, the part of an ovule where nucellus and integuments cohere; the base of the nucellus.

Chalazogamic, applied to fertilization in flowering plants via the chalaza and not by the micropyle, *e.g.* in the Hazel.

Chlamydospore, the reproductive organ in some Fungi.

Chloranthy, the production of green flowers; a supposed reversion of floral structures to a primitive foliar condition.

Chlorenchyma, a term sometimes given to a green, chlorophyll-containing tissue.

Chlorophyll, the ordinary green pigment of plants which is the agent in the process of carbon assimilation.

Chlorophyll-corpuscles, protoplasmic bodies distinct from, yet imbedded in, the general cell-protoplasm of the green parts of plants. The chlorophyll is restricted to these corpuscles.

Chromatophore, a general term for any protoplasmic body containing a pigment. Chlorophyll-corpuscles are chromatophores.

Chromosomes. See *Fibrils*.

Cilia, delicate protoplasmic filaments serving as organs of locomotion, as in zoospores, &c.

Cincinnus, a form of cymose inflorescence, a one-sided cyme.

Cirrhus capreolus, a term for stem-tendrils, *i.e.* branch-tendrils and flower-stalk tendrils.

Cirrhus costalis, a projecting or excurrent midrib, modified as a tendril.

Cirrhus foliaris, a leaf modified as a tendril.

Cirrhus peduncularis, a flower-stalk modified as a tendril.

Cirrhus petiolaris, a petiole or leaf-stalk modified as a tendril.

Cirrhus radicalis, a root modified as a tendril.

Cirrhus rameaneus, a tendril which is a modified branch.

Cirrhus stipularis, a tendril which is a metamorphosed stipule.

Cladodes, leaf-like branches. See *Phylloclade*.

Clamp-cells, here used for the papilla-like cells by which an epiphytic root adheres to the substratum.

Class, the highest grade or division of plants in the system of Linnæus. In our system a class is subordinate to a phylum, and the classes are subdivided into alliances.

Clavate, club-shaped.

Claw, a name given to the stalk of a petal.

Cleistogamic, -ous, a term applied to the inconspicuous flowers produced by many plants. These flowers do not open, and are self-pollinated (autogamous).

Cob, a term applied to the spike on which Maize grows.

Cœnobe, or **Cœnobium**, a colony of separate organisms united by a common investment, *e.g.* Volvox.

Coherent, used of the union of similar members.

Cohort, a group of families or orders which are nearly related to one another; is used here as synonymous with Alliance.

Collective fruit, a fruit in which the products of a number of *separate* flowers become so crowded together as to appear as though they had arisen from a single flower, as the Pine-apple. Cf. *Aggregate fruit.*

Collenchyma, a living tissue, consisting of prism-shaped cells whose angles are much thickened. It is a form of mechanical tissue.

Colony. See vol. i. p. 585.

Columella, in Muscineæ, the sterile tissue in the centre of the sporogonium around which the spore-layer is formed.

Column, the body formed as a result of fusion of stamens with style, as in Orchid flowers.

Conceptacle, the inclosing cavity in which the sexual organs are produced in the Fucaceæ.

Cone, the aggregate of crowded scales which bear ovules or pollen-sacs in the Gymnosperms; applied also to the sporangiferous branches in many Vascular Cryptogams.

Conidium, in Fungi, a propagative asexual body.

Conifer, a plant producing cones; one of the Coniferæ.

Conjugation, the union of two gametes (or sexual cells), the resulting organism being called a *zygote.*

Conjugation-canal, the bridge which is formed between conjugating cells of Spirogyra, &c., and by which impregnation is effected.

Connate, united congenitally.

Conopodium, a conical receptacle (used of flowers).

Contorted æstivation, used when the corolla appears spirally twisted, the petals being so arranged that one margin is external to a neighbouring petal whilst the other is internal to the petal on the other side.

Contractile cells, in the anther, form a layer in its wall; their membranes are peculiarly thickened, and by their hygroscopic contractions the anther opens.

Convolute, applied to a leaf which is rolled up longitudinally in the bud.

Cordate, heart-shaped, as a leaf.

Corm, a bulb-like fleshy stem or base of a stem; a "solid bulb", as in Crocus, Colchicum, &c.

Cormus. See foot-note, vol. i. p. 665.

Corolla, the inner whorl of the perianth, composed of petals.

Corona, in Narcissus, &c., a series of ligular structures on petals, which may be either free or united together. It gives the appearance of an additional floral whorl.

Corpuscle, a little mass of protoplasm which though imbedded in the general protoplasm of the cell is nevertheless an independent body, *e.g.* chlorophyll-corpuscle.

Corpusculum (of Asclepiad pollinium), the little body connecting the pollen-masses and by means of which they become attached to insects.

Cortex, the portion of a stem or root external to the vascular tissues.

Corymbus, or **Corymb**, a flat-topped inflorescence belonging to the centripetal or indefinite series.

Cosmic dust, the minutely divided inorganic particles suspended in the higher strata of the atmosphere; not necessarily of extra-terrestrial origin.

Cosmopolitan plants are such as range almost over the entire globe; in contrast to plants that flourish only in a certain locality (*endemic* plants).

Cotyledons, seed-leaves; the first leaf or leaves of an embryo.

Craspedromous, used of the lateral veins of a leaf which run undivided from midrib to margin.

Crateriform, goblet- or cup-shaped.

Crenate, said of a toothed leaf-margin, the teeth being rounded; scalloped.

Cross-fertilization, the fertilization of an egg-cell by a male cell borne on another individual; fertilization of the ovules of one flower by the pollen from another individual. Occasionally used in error in the text for cross-pollination (which see). Many authors use the term as synonymous with cross-pollination, but the practice is not good.

Cross-pollination, the deposition on a stigma of pollen which has been brought from another flower. Cross-pollination, though probably leading to cross-fertilization, is not synonymous with this term.

Cruciferous, "cross-bearing", having cross-shaped flowers: used of the characteristically flowered family Cruciferæ.

Cryptogamia, includes all plants exclusive of Flowering Plants: opposed to *Phanerogamia.* An old term, persisting from times when the reproductive processes of these plants were less well-known than to-day.

Crystalloid, a crystal-like mass of proteid; a common form under which proteids are stored.

Culmus, or **Culm**, the jointed and usually hollow stem of Grasses and similar plants.

Cupule, the bract-like cup which incloses the nut or nuts in many Amentiferæ; it is the husk of the hazel-nut, the cup of the acorn, the prickly envelope of the Spanish chestnut, &c.

Cut, a term applied to the lobing of leaf-blades; incised; cleft.

Cuticle, a continuous film on the surface of a plant, formed of the cutinized outer surfaces of the epidermal cells.

Cyma, or **Cyme**, a definite or centrifugal inflorescence: the laterals grow more strongly than the primary axis and overtop it.

Cyma composita, or compound cyme; a definite or centrifugal inflorescence, in which the ultimate parts (cymes) are also arranged in a cymose manner.

Cystolith, a concretion of carbonate of lime, generally deposited on a little tongue or peg of cellulose projecting into the cells of certain plants.

Cytoplasm, the protoplasmic body of a cell as opposed to the nucleus.

Daughter-cells, cells which arise by the division of any cell.

Deciduous, non-permanent: used of parts of a flower (petals, &c.) which fall after flowering, and of leaves which fall in autumn, &c.

Decurrent, used of leaf-blades which have their bases extending downward along the stem.

Decussate, applied to leaves which are arranged in pairs alternately crossing each other at regular angles.

Definitive nucleus, the nucleus which is formed in the embryo-sac by the fusion of two, one from each end; the endosperm originates from it after fertilization has taken place.

Dehiscence, the act or mode of opening of a fruit, anther, spore-capsule, &c. &c.

Dendritic, tree-like; repeatedly branched.

Denizen, an inhabitant, a plant belonging to a certain district. Strictly (but not so used in K. and

O.), a plant resembling a native, but suspected of having been originally introduced.

Dentate, of leaf margins; toothed—the teeth pointing *outwards*, not forwards or backwards.

Dermatogen, the embryonic cellular layer at the apex of a stem or root from which the epidermis is developed.

Desmid, one of the Conjugatæ. See vol. ii. p. 655.

Dextrorse, used of twining plants which turn from west through south to east, &c.

Diadromous, having a fan-like arrangement of leaf-veins, as in Gingko.

Dialypetalæ, plants with petals separate from one another (= Polypetalæ).

Diandria, the 2nd class of Linnean system; includes all genera with perfect flowers having two stamens.

Diastase, a solid, white, soluble substance found in Oats, Potatoes, &c., after germination.

Diastole, used of the rhythmic expansion of a contractile cell or vacuole.

Diatom, a single organism inclosed in a bivalved siliceous test or frustule. See vol. ii. p. 625.

Diatomin, the brown pigment of Diatoms.

Dichogamy, the maturing of pollen and stigma in a hermaphrodite flower at different times, to prevent self-fertilization.

Dicotyledon, plant with two seed-leaves or cotyledons.

Dictyodromous, or reticulate venation, are terms applied to lateral veins of leaves which break up into a network before reaching the margin.

Didynamia, the 14th class of the Linnean system, which includes flowers with four stamens, two long and two short.

Didynamous, applied to flowers having four stamens, one pair longer than the other.

Diœcious, unisexual; the male and female flowers being on separate plants.

Diosmosis, the transfusion of a fluid through imperceptible openings in a membrane.

Diptero-cecidia, gall-structures, due to dipterous insects.

Discoid, resembling a disc.

Discomycete, any Fungus belonging to the group Discomycetes, *i.e.* an Ascomycete in which the fruiting body is disc-shaped.

Discomycetous, pertaining to the group of Fungi Discomycetes.

Discopodium, a disc-shaped floral receptacle.

Disintegration, a resolution of a tissue into its constituent cells, or of any body into its constituents.

Displacement, in whorls, applied to the shifting of places of insertion of members, so that successive whorls are placed immediately above one another.

Divergence, applied to the angle between the insertions of successive leaves on a stem.

Divided, used of leaf-blades to express the fact that they are deeply lobed.

Dormant eyes or buds, or **Reserve-buds**; are buds which arise in the leaf-axils in the usual way, but which do not forthwith expand into shoots; they remain—often many years—until stimulated into activity by some special event.

Drupaceous, of the nature of a drupe.

Drupe, a succulent fruit with hard, stony endocarp, which incloses a single seed. Many-seeded drupes are rare.

Duct, a continuous tube, arising either by the running together of cells (fusion), or by the separation of cells, when it is lacunar in nature; a canal formed by a row of cells having lost their partitions.

Dwarf-male, of Œdogonium; the little few-celled plant arising from an androspore which gives rise to the spermatozoids. It is formed adjacent to the oogonium.

Ectoplasm, the pellicle-like outmost layer of protoplasm in a cell. It is clear and hyaline, and less fluid than the endoplasm.

Egg-cell, or **Ovum**; the female generative cell.

Elaters, (1) in Liverworts, filamentous cells, with spiral thickenings, which are present with the spores, and, owing to their hygroscopicity, assist in their dispersal; (2) in Equisetum, arm-like appendages of the spores, by the contractility of which the spores become entangled in groups.

Ellipsoidal, having the form of an elliptical solid.

Embryo, the rudimentary plant; in seeds, that stage of the young plantlet at which the resting-stage supervenes.

Embryo-cell, the cell borne at the distal end of the suspensor, which gives rise to the embryo, or to the greater part of it.

Embryo-sac, the large cell in the nucellus of an ovule, in which the egg-cell, and ultimately the embryo, arises.

Endemic, restricted to a given region or locality.

Endophytic, living within the tissues of another plant, though not necessarily parasitic upon them.

Endoplasm, the soft, inner granular protoplasm of a cell.

Endosmosis, the transmission of fluids through porous membranes from the exterior to the interior.

Endosperm, the tissue produced within the embryo-sac of flowering plants, and which in many cases becomes stored with food-materials for the embryo.

Endospores, asexual reproductive cells produced inside the original cells in Bacteria.

Endothecium, in flowering plants, the layers of the wall of the anther internal to the exothecium.

Ennobling, the art of transferring a branch or bud of one plant to another, and causing them to unite.

Entire, untoothed: applied to the leaf-margin, petals, &c.

Entomophilous plants, such as have flowers pollinated by insect agency.

Enzyme, any of the unorganized ferments which exist in seeds, as diastase, pepsin, &c.

Ephemeral, applied to flowers which endure only for a few hours or for a day; opening but once.

Epicotyl, the portion of a plant above the cotyledons; restricted to embryos and seedlings.

Epidermis, that layer of cells which forms the enveloping mantle of multicellular plant-bodies. It may be replaced in perennial plants by cork.

Epigeal, growing above the ground.

Epiphragm, of Mosses: the membrane remaining after the fall of the operculum, stretched across the mouth of the capsule in Polytrichaceæ.

Epiphyllous, applied to structures growing on leaves.

Epiphytes, plants growing attached to other plants (or animals), but not parasitically.

Equitant, riding; folded around, as if straddling over.

Erythrophyll, a red sap-pigment frequent in foliage-leaves, especially in autumn.

Ethereal oils, oils of wide occurrence in plants, and of various chemical composition; to the presence of these ethereal or volatile oils are due most of the odours of plants.

Evolute, turned back.

Exalbuminous, applied to seeds which are destitute of endosperm or perisperm, the food-material being stored in the embryo itself.

Excoriation, of glandular hairs; applied to the act of throwing off the cuticle as a blister.

Exfoliate, to come away in scales or flakes, as the bark of a tree.

Exine. See *Extine.*

Exogamy, the tendency often exhibited by closely related gametes to avoid pairing.

Exosmosis, the passage from within outwards of fluids through a membrane.

Exothecium, the outmost layer or epidermis of an anther.

Exstipulate, without stipules: often used (though erroneously) in cases where the stipules are early deciduous.

Extine, the outer coat or membrane-layer of a pollen-grain. It is, however, internal to the perine.

Extravasation, an escape from the proper vessels into surrounding tissues: used of fluids.

Extrorse, applied to such anthers as open towards the outer whorls of a flower, *i.e.* away from the gynœceum.

Eye, of Potato, &c.; an undeveloped bud.

Eye-spot, in motile gametes and spermatozoids, a little red pigment-body contained usually in the anterior extremity, and supposed to be sensitive to light. Cf. vol. ii. p. 629.

Fairy-ring, a phenomenon observed in meadows, and due to the growth of certain Fungi. Cf. vol. ii. p. 792.

Fasciation, used of monstrous expansions of stems, which resemble several stems fused together in one plane.

Fascicula, or **Fascicle**, a dense cluster of flowers, leaves, roots, &c.

Father-plant, the stock from which the pollen is derived: used in connection with hybrids.

Ferment, a substance produced by the protoplasm, which induces chemical change or fermentation in some substance without itself entering into or being affected by the process.

Fertilization, the process by which the pollen reaches and acts upon the ovules, and results in the production of fruit; impregnation.

Fertilizing-tube, in Peronospora, the tubular outgrowth of the antheridium which penetrates the oogonial wall and by which the male substance passes to the egg-cell.

Fibre, any delicate filament; also, a thick-walled tapering cell.

Fibrils of nucleus; the segments into which the nuclear reticulum breaks up at division; they are also termed *chromosomes.*

Fibrous layer, of anther: the specially thickened portion of the wall which brings about dehiscence.

Filament, the stalk of an anther.

Filiform, slender, thread-like.

Fimbriate, fringed by fine subdivision of the margin; having fine, hair-like marginal processes.

Fistular, hollow, reed-like.

Flagellum, the whip-like process or filament of protoplasm which serves as an organ of motility; also a shoot sent out from the bottom of a stem, as in the strawberry; a runner.

Floccose, composed of or bearing soft hairs or wool.

Flora, the aggregate of the plant-population of any district; also, the term given to a systematic description of the same.

Floral, belonging to the flower.

Floret, a small flower in a cluster or in a compact inflorescence, as in the Compositæ.

Flower, in Phanerogams the growth which comprises the reproductive organs and their envelopes; a shoot modified for the production of spores (pollen-grains and embryo-sacs).

Flowering glume, the outer of the two chaffy scales inclosing the several flowers of a grass; it is frequently awned.

Folium fulcrans, the subtending leaf of a flower; a bract.

Follicle, a monocarpellary dehiscent fruit opening only down the ventral suture.

Foot, the sucker by means of which a young Fern-plant is temporarily attached to the prothallium.

Foreign, applied to pollen from another flower.

Frugivora, animals which live upon fruits.

Fruit, defined vol. ii. p. 47.

Frustule, the siliceous valve of a Diatom.

Frutex, a shrub.

Fruticose, pertaining to shrubs; shrubby.

Fruticulus, a little shrub.

Fuliginous, having the colour of soot.

Fundamentum, the hypocotyl, which see.

Fungus, a cellular Cryptogam, distinguished for its want of chlorophyll; it is either saprophytic or parasitic.

Funicle, the stalk of an ovule or seed; a funiculus.

Furfuraceous, scurfy; covered with bran-like scales.

Fusiform, spindle-shaped: applied to roots, &c., which taper both ways from the middle, as the radish.

Galeate, helmet-shaped; having a galea or helmet.

Gall, a vegetable excrescence produced by the deposit of the egg of an insect in the bark or leaves of a plant; a hypertrophied growth due to some irritating cause.

Gametangia, cells from which gametes are developed.

Gamete, a sexual cell.

Geitonogamy, crossing between separate flowers growing on the same plant.

Gemma, a small undeveloped shoot; a shoot-bud.

Gemmation, the act or process of budding.

Generative cell, in pollen-grains, that cell which ultimately fertilizes the egg-cell.

Genetic spiral, the spiral line passing through the point of insertion of equivalent lateral members (leaves) on an axis in order of age from older to younger.

Genus, an assemblage of species; its name, together with that of the species, gives the name to the plant.

Geotropism, applied to the power or tendency of some plants to grow towards the earth.

Germen, the ovary.

Germination, the act, process, or result of evolving the embryo of a seed into a young plant.

Gills, the radiating plates on which the basidiospores of Agarics are produced.

Glabrous, without hairs; quite smooth.

Glandular, having the nature of a gland, bearing glands.

Gleba, the chambered, sporogenous layer of a Gasteromycetous Fungus.

Globoid, the tiny mass of magnesium and calcium phosphate which is often present in aleurone grains (which see).

Glomerule, a cymose inflorescence formed into a head, as in the Globe-thistle.

Glucoside, a compound consisting of glucose and an aromatic body.

Glumes, the chaffy, bract-like scales on the inflorescences of Grasses and Sedges.

Goneoclinic, used of hybrids which approximate to one or other parent-form rather than standing midway between them.

Graft-hybrid, a hybrid supposed to have arisen by budding or grafting.

Gynandria, the 20th class of the Linnean system. Cf. vol. ii. p. 290.

Gynœceum, the carpel, or aggregate of carpels, in a flower; the female portion of a flower as a whole.

Habitat, the natural abode of a plant.

Hæmatochrome, the red pigment found in the eye-spots of Chlamydomonadeæ and zoospores.

Halophytes, plants which flourish on soils rich in salt; saltworts.

Haulm, the stalk of a grass of any kind.

Haustorium, the sucker of a parasitic plant.

Herbaceous, of the colour, texture, &c., of a herb.

Herbal, a book of descriptions of plants with especial reference to their medicinal properties; herbals were usually copiously illustrated.

Herbarium, a collection of dried plants systematically arranged. (Formerly it signified an illustrated herbal.)

Hermaphrodite, applied to a flower which has both stamens and carpels.

Heterochromatism. *Vide* vol. ii. p. 569.

Heterœcism, the act of passing through different stages of development on different hosts; as in Fungi.

Heterogamous, applied to plants that bear two kinds of flowers which differ sexually.

Heterogamy, the state or quality of being heterogamous (which see); cross-pollination.

Heteromorphism, here used to designate the various modifications of equivalent members in connection with different functions, analogous to that existing among the polyps of a coral.

Heterophyllous, bearing leaves of more than one form on the same stem; applied especially in respect of foliage-leaves.

Heterosporous, having spores of different kinds, especially macrospores and microspores.

Heterostyled, when the flowers of a plant differ in the relative length of their styles: opposed to *homostyled*.

Hilum, (1) of starch-grain; the centre around which the stratifications are deposited; (2) of a seed; the scar or place of attachment.

Hirsute, bearing rather stiff hairs.

Holosericeus, covered with fine silky hairs.

Homochromatism. *Vide* vol. ii. p. 569.

Homosporous, having spores all of a kind.

Homostyled. See *Heterostyled*.

Hortus vivus, an old term for a dried collection of plants, now called a *herbarium* (*hortus siccus* is also used in the same sense).

Humus, vegetable mould; a soil largely composed of decaying vegetable matter.

Hybrid, a plant resulting from the intercrossing of more than one species.

Hybridization, the act of crossing different species and so producing hybrids.

Hydrophytes, plants which live in water.

Hydrotropism, the particular irritability of plant-members (especially roots) whereby they respond by curvatures to moisture in the environment, turning towards or away from it.

Hymenium, hymenial layer; the spore-bearing surface of a fungal receptacle.

Hypanthium, a term given to any special enlargement of the receptacle, as in the Rose.

Hypha, the filamentous element of the thallus of a Fungus.

Hyphodromous, used when the veins of a leaf run so that they are not visible on the surface.

Hypocotyl, the portion of the stem below the cotyledons.

Hypocrateriform, salver-shaped: used of corollas, &c., which are tubular below and suddenly expand into a flat limb.

Hypogeal, underground; growing beneath the surface of the earth.

Hysterophyta, Endlicher's term for the parasitic flowering plants.

Idioplasm, name applied by Nægeli to that portion of the protoplasm in which the formative activity was supposed to reside — the active, organizing portions of the protoplasm.

Illegitimate union in heterostyled flowers. *Vide* vol. ii. p. 405.

Imbricate æstivation. *Vide* vol. ii. p. 210.

Imbricating, overlapping like the tiles of a roof.

Incised, of leaves, cut irregularly and sharply.

Indumentum, a hairy covering or coating.

Indusium, the scale-like outgrowth of a Fern leaf enveloping the sorus.

Inferior, (1) of the ovary; adherent to the calyx (cf. also vol. ii. p. 79); (2) of the calyx, free from the ovary; (3) in regard to the relation of parts of flower to the axis; farthest from the axis.

Inflorescence, the mode of branching of the flower-bearing part of a plant; or, the actual cluster of flowers (the common use of the term).

Infundibuliform, Infundibular, funnel-shaped.

Innovatio, a new-formed shoot.

Insectivorous plants, plants which catch insects and absorb their juices.

Integument, the envelope—single or double—of an ovule.

Internode, the portion of a stem between the points of insertion of leaves.

Intine, the internal layer of the wall of a pollen-grain.

Introrse, of the anther; dehiscing towards the centre of the flower.

Intussusception, the taking up by a living organism of new particles between those already in existence.

Invertin, a ferment which converts cane-sugar into glucose.

Involucral, appertaining to the involucre.

Involucre, a circle of bracts inclosing a capitulum or other crowded inflorescence.

Involute, rolled inward.

Isogametes, equivalent gametes or sexual cells.

Isoplanogametes, in Algæ; motile sexual cells which are equal in size.

Kamptodromous. See vol. i. p. 630.

Labellum, the median member of the inner perianth-whorl in Orchids.

Laciniated, cut into narrow lobes.

Lacuna, a space, especially an intercellular space, originating by the separation or breaking down of cells.

Lamella, a thin plate as in the gills of Agarics. See *Gills.*

Lanceolate, shaped like a lance-head; narrower than oblong, and tapering towards the apex.

Latex, plant juice, often a milky juice.

Laticiferous, containing latex.

Leaf-axil, the angle formed by a leaf and the portion of stem immediately above its point of insertion.

Leaves, laterally-developed members of limited growth, which spring in geometrical succession from the outer layers of tissue below the growing point of the stem.

Legitimate union, in heterostyled flowers. *Vide* vol. ii. p. 405.

Legume, or **Pod**; a monocarpellary fruit dehiscing down both sutures.

Lepidote, -us, beset with scurfy scales.

Liane, Liana, a climbing plant with a woody, perennial stem.

Libriform cells, strong, spindle-shaped cells with inconspicuous pittings, thick walls, and usually destitute of protoplasmic contents. They occur in wood.

Lichen, an organism compounded of a Fungus and an Alga living together symbiotically.

Lignin, an aromatic substance (or number of substances) present in the membrane of woody tissue. To it are due the characteristic properties of wood.

Ligulate, provided with a ligule.

Ligule, Ligula, (1) the thin scarious projection from the summit of the leaf-sheath in Grasses; (2) the corolla of a ray-floret in the Compositæ; (3) a tongue-like outgrowth on the leaf met with in Selaginella and Isoëtes just above the insertion of the sporangium.

Linear, several times narrower than long, with the margins parallel.

Linear-lanceolate, intermediate in form between linear and lanceolate.

Lines of vegetation, for any species, are the lines obtained by joining all the places in a given direction at which that species is checked in its distribution by climatic or other conditions; the resultant figure obtained by joining all the lines of vegetation covers the distribution of the species in question, and may be termed the line of distribution.

Lithophytes, plants which grow on stones, and derive their nutriment in the main from the atmosphere.

Liverwort, a term applied to any member of the Hepaticæ.

Lobe, any division of an organ; a rounded projection or division.

Lodicules, tiny scales, usually two in number, which occur in the flowers of Grasses, and are supposed to represent the perianth.

Lomentum, a legume which separates into 1-seeded articulations or joints.

Macropodous, applied to embryos in which the hypocotyl is enormously enlarged, constituting the greater part of the embryo.

Macrospores, used of the larger (so-called female) spores of heterosporous plants: opposed to *microspores.*

Manubrium, the cell in the antheridium of Characeæ which projects inwards from the shield, and ultimately bears the antheridial filaments.

Medulla, pith.

Megagametes, used of the larger, and presumably female, motile sexual cells of certain Algæ.

Melliferous, honey-bearing.

Mericarp, one of the achene-like fragments into which a syncarpous, polycarpellary fruit (schizocarp) breaks up. Used especially of Umbelliferæ.

Meristem, embryonic tissue: growing cell tissue at the ends of young stems, roots, &c.

Mesophyll; the whole of the internal ground-tissue of a leaf-blade.

Metabolism, the chemical changes which take place in the protoplasm and which it causes in other substances; the phenomena resulting from chemical changes in the protoplasm.

Micellæ, name given to molecular aggregates, just as molecule is the name given to atomic aggregates.

Microgametes, used of the smaller, presumably male, motile sexual cells of certain Algæ.

Micro-millimeter (μ), the one-thousandth part of a millimeter.

Micropyle, the aperture left in the integument of an ovule by means of which the pollen-tube gains access (except in chalazogamic plants) to the embryo-sac.

Microsomata, tiny granules of various nature embedded in the protoplasm. Not a good term.

Microspores, the smaller or so-called male spores of heterosporous plants: opposed to *macrospores.*

Midrib, the central or main vascular bundle of a leaf.

Monadelphous, when the stamens are all united together by their filaments into a tube or column.

Monandria, the 1st class of the Linnean system. See vol. ii. p. 288.

Moniliform, like a necklace or string of beads.

Monocarpellary, consisting of one carpel.

Monocotyledonous, having only a single cotyledon or seed-leaf.

Monœcia, the 21st class of the Linnean system. See vol. ii. p. 290.

Monœcious, having male and female flowers on the same individual.

Monotypic, term used of genera which comprehend but a single species, *e.g.* Welwitschia.

Morphology, that department of botanical study which deals with the form of the plant-body, including its development, the growth of its distinct members, &c.

Mother-plant, that parent of a hybrid upon which the seed is matured.

Mycelium, the filamentous vegetative body of a Fungus.

Myco-cecidium, a gall which owes its origin to the attacks of Fungi.

Mycorhiza, a root invested by a fungal mantle: supposed to be a case of symbiosis.

Mycosis, a diseased condition of animal tissues alleged to be due to the presence of a Mould-fungus.

Myrmecophilous, used of plants which attract ants, the latter often living altogether upon the plant and affording it protection against certain enemies.

Nectary, a honey-secreting gland or part of a flower.

Neroli, Oil of, the ethereal oil yielded by the flowers of the Orange-tree.

Neuter flowers, flowers destitute of functional stamens or carpels.

Node, the part of a stem at which a leaf or whorl of leaves is inserted.

Nodose, or **Nodosus**, knotty; having well-marked nodes or knots.

Nodulated, having small knots: diminutive of *nodose*.

Nucellus, the central portion or body of an ovule, containing the embryo-sac.

Nuclear plate, the assemblage of nuclear fibrils in the equator of a nucleus during the division of the latter.

Nucleus, (1) of starch-grain, same as hilum; (2) of an ovule, an old term for *nucellus*; (3) the cell-nucleus, a specialized portion of the protoplasm of a cell exhibiting remarkable figures during division and presiding over the chemical processes that take place in the cell.

Nut, a hard, indehiscent, 1-seeded fruit resulting from a polycarpellary ovary.

Nutation, spontaneous changes in position of growing organs; a kind of oscillation or regular movement in parts of plants.

Obovate, ovate with the broader end at the apex.

Omphalodium, the scar at the hilum of a seed.

Ontogeny, the history of the individual development of an organized being.

Oogonium, the cell in which the female sexual cell or cells are produced; especially amongst Thallophytes.

Oophyte, that stage in the life-cycle of a plant which bears the sexual organs.

Ooplasm, the substance of which the female sexual cell consists. Not a good term.

Ooplast, the female sexual cell. Not a very good term.

Oospore, a fertilized egg-cell.

Operculum, the lid of a Moss capsule.

Order, a division of plants intermediate between class and genus, consisting usually of a group of genera related to one another by structural characters common to all. Same as *family* as used in this book.

Orthostichies, vertical ranks of leaves. Cf. vol. i. p. 397.

Orthotropous, applied to an ovule with straight nucellus wherein the micropyle is at a point far removed from the funicle.

Osmosis, the tendency of fluids to pass through porous membranes; the phenomena attending the passage of fluids through porous membranes.

Ostiole, the aperture of the conceptacle in the Fucaceæ.

Ovary, the part of the pistil that contains the ovules or immature seeds; the closed chamber-like portion of a single free carpel, or the many chambers of several united carpels in which the ovules are produced.

Ovule, in Phanerogams is the macrosporangium or nucellus with its integuments, and containing the embryo-sac. The ovule is the immature seed.

Ovuliferous scale, the ovule-bearing scale of Conifers.

Palæo-botany, Fossil botany.

Palate, a projection in the throat of a personate corolla (or corolla such as that of the Snapdragon).

Palea, the inmost of the glumes which inclose the individual flowers of Grasses; a chaffy scale or chaff-like bract.

Palisade-cells, the green assimilating tissue, consisting of cylindrical cells, usually found towards the upper surface of the leaf-blade.

Palmate (of leaf-blades), lobed so that the projections radiate from the point of insertion.

Panicle, a loose branched cluster of flowers. Not applied very strictly.

Papilionaceous, like a butterfly: a term applied to the corolla of a section of Leguminosæ, including the Pea and Bean, &c.

Papilla, a minute nipple-shaped projection.

Papillose, bearing papillæ.

Pappus, the hairy or feathery development of the calyx of a Composite plant, which promotes dispersal by wind; thistle-down or the like.

Parallelodromous. See vol. i. p. 634.

Paraphyses, sterile filaments accompanying the sexual organs in Mosses, the asci and basidia of Basidiomycetes, and in other cases.

Parasite, a plant which lives upon and obtains organic nutriment from the tissues of a living plant (or animal).

Parastichies, secondary spirals in the arrangement of leaves.

Parenchyma, usually thin-walled tissue consisting of cubical or polygonal cells, and forming the pulp of leaves, fruits, &c.

Parthenogenesis, the development of an egg-cell into an embryo without fertilization taking place.

Parthenogonidia, certain reproductive cells in a Volvox-colony which propagate the plant asexually.

Partite, cleft, but not quite to the base.

Patelliform, disc-shaped; circular with a rim.

Pedate venation. See vol. i. p. 633.

Pedicel, an ultimate flower-stalk bearing a single flower.

Pedunculus, or **Peduncle**, a general flower-stalk bearing either a single flower or a closely-crowded cluster of flowers.

Peltate, shield-like: said of leaves when the petiole is attached to the under surface of the blade and not to the margin.

Perfoliate, appearing as if perforated by a stem: said where a stem is so embraced by a leaf that the former seems to pass through the latter.

Perianth, the floral envelopes, consisting of calyx or corolla, or both: used especially when it is not easy to distinguish between them.

Periblem, the embryonic tissue at a growing point from which the primary cortex arises.

Pericarp, -ium, the wall of an ovary that is developed into a fruit.

Perichætium, the sheathing structures in Muscineæ which envelop the clusters of archegonia and antheridia.

Peridium, the outer envelope investing the fructification in certain Fungi.

Perine, the outmost layer of sculpturing on the membrane of pollen-grains.

Perisperm, the tissue of the nucellus, in which, sometimes, food material is stored for the ultimate use of the embryo. It is external to the embryo-sac. In many old systematic books it is used for all food-material of seeds which is external to the embryo.

Peristome, the ring of teeth around the mouth of a Moss capsule.

Perithecium, the flask-shaped cavity in which asci are produced in certain Fungi.

Petal, a corolla-leaf.

Petaloid, -ine, like a petal.

Petiole, the stalk of a leaf.

"**Petit grain**", name for the ethereal oil yielded by the leaves of the Orange-tree.

Phænology, that branch of botanical investigation which deals with the recording, tabulation, and comparison of the times and seasons at which plants open their flowers and perform other periodic functions in various portions of the globe.

Phanerogamia, seed-bearing or flowering plants.

Phloem, soft bast; the soft outer portion of a vascular bundle, of which sieve-tubes are the most characteristic constituents.

Phrygana, an old term for a growth of stiff and prickly under-shrubs.

Phycocyanin, the blue pigment of the Cyanophyceæ or lowest Algae.

Phycophæin, the brown pigment of the Brown Algæ.

Phycoerythrin, the purple colouring-matter of Red Sea-weeds.

Phylloclade, a branch assuming form and function of a foliage-leaf: same as *cladode*.

Phyllode, a petiole assuming the form and function of a leaf-blade.

Phyllotaxis, leaf-arrangement; the arrangement or order of distribution of leaves on the stem.

Phylogeny, or **Phylogenesis**, the history of the genealogical development of an organized being; the race history of an animal or plant, as distinguished from *ontogeny*, the history of individual development.

Phylum, a main division of the vegetable kingdom.

Pileus, the cap-shaped receptacle of a Basidiomycetous Fungus; the umbrella-like part of a mushroom.

Pili fasciculati, tufted hairs.

Pili stellati, stellate hairs.

Pinnate, when leaflets are arranged on either side of a common rachis or petiole.

Pistil, the female organ of a flower, consisting of ovary (style) and stigma; if the carpels are apocarpous there are many pistils; if syncarpous, only one.

Pistillate, said of a plant or flower containing a pistil; most correctly, of one having no stamens.

Pitcher, a tubular or excavated leaf, usually containing a liquid; an ascidium.

Pith, the central cellular part of a stem or root.

Pits, thin places or depressions on cell-walls.

Placenta, the part of the carpel which bears the ovules; in Vascular Cryptogams, the portion of leaf-surface bearing the sporangia.

Plaited, folded; folded into plaits lengthwise; plicate.

Plant-formation, a term used to indicate the presence of two or more types of plant-community intermingled together, often in obvious strata. Cf. vol. ii. p. 896.

Plasmodium, in the Myxomycetes; a mass of naked multi-nucleate protoplasm exhibiting amœboid movements.

Pleomorphism, the occurrence of more than one independent form in the life-cycle of a species, especially in Fungi and Bacteria.

Pleurocarpous, used of Mosses in which the archegonia are borne, not at the tips of the main but of secondary shoots.

Plicate, of æstivation; folded lengthwise in plaits.

Plumule, the rudimentary shoot of an embryo.

Pod. See *Legume*.

Podium, a term for the torus or floral receptacle.

Polar nuclei, the two nuclei—one from each end of the embryo-sac of Angiosperms—which approach one another and fuse to form the definitive nucleus of the embryo-sac.

Pollarding, the act of removing the crown of a tree so as to induce it to throw out branches around the place of amputation.

Pollen, the mass of fecundating cells or grains contained in the anther.

Pollen-grain, one of the fecundating cells of the pollen; the microspore in flowering plants.

Pollen-sac, the sporangium in which the microspores or pollen-grains of flowering plants are developed.

Pollen-tube, the tubular outgrowth of a pollen-grain by means of which fertilization is achieved.

Pollinia, masses of coherent pollen-grains.

Polycarpellary, having or consisting of a number of carpels.

Polychotomous, branching repeatedly into equivalent portions.

Polyembryony, the production of more than a single embryo in an ovule.

Polyhedra, angular bodies which arise from the zoospores into which the zygote of Hydrodictyon breaks up. Ordinary Hydrodictyon-nets arise inside them.

Porogamic, used of flowering plants in which the pollen-tube effects an entrance to the ovule by the micropyle.

Porous, used of dehiscence of anthers, &c., by means of holes.

Prickle, a sharp-pointed process of the epidermis or cortex, but destitute of vascular tissue.

Primordial utricle, that portion of the cell-protoplasm which forms a bag in contact with the cell-wall. An old name which has persisted in the terminology.

Procumbent, lying along the ground.

Prolepsis, something of the nature of an anticipation. See vol. i. p. 8.

Pro-mycelium, the limited tubular growth arising from the chlamydospores in Hemibasidii and Uredineæ, from which conidia are abstricted.

Prostrate, lying flat on the ground.

Protandrous, Proterandrous, used of flowers when the anthers dehisce before the stigmas are receptive.

Proteid, a nitrogenous substance of complex constitution, generally of a viscid nature and rarely crystallizable. The proteids include albumin, globulin, peptone, &c.

Prothallus, -ium, the structure produced by the germination of the spore of Ferns, bearing sexual organs, and from which the young plant arises and derives nourishment for a time; also the homologue of this in flowering plants.

Protogynous, Proterogynous, used of flowers in which the stigmas are receptive before the pollen of the same flower is discharged.

Protonema, the filamentous growth of a Moss from which the leafy shoots arise by budding.

Protoplasm, the living and formative organic substance of plants and animals; living matter in its simplest form, serving as the basis of both animals and plants, and consisting of carbon, oxygen, hydrogen, and nitrogen, colourless, transparent or nearly so, and somewhat viscid in consistence.

Protoplast, the protoplasmic cell-body; a simple one-celled organism.

Pseudo-hermaphrodite flowers are such as have been functionally unisexual by the suppressing of either stamens or carpels.

Pseudomorph, a term borrowed from mineralogy; an unusual or altered form. Cf. vol. i. p. 185.

Pulverulent, powdery.

Pulvinate, cushion-like.

Pulvinus, the enlargement of a petiole or leaf-stalk at its point of insertion on the stem, or of a secondary petiole at its point of insertion on the leaf-rachis.

Pycnidium, in Fungi; a receptacle or cavity of varying form, in which conidia (pycno-conidia) are produced: especially in Ascomycetes.

Pyrenoids, refractive bodies imbedded in the chlorophyll of many Green Algæ.

Race, a variety or form not distinguished by characters important enough to rank as a species, but reproduced by seed and transmitting its characters to the offspring; also loosely used for a group of allied individuals without regard to rank.

Racemus, Raceme, an indefinite or centripetal inflorescence with pedicellate flowers.

Rachis, the axis of a compound leaf, or of a spike or other indefinite inflorescence.

Radical, belonging to or arising from a root, or from a root-like portion of the stem below the ground.

Radices adligantes, clinging roots.

Radices columnares, columnar roots.

Radices fulcrantes, stilt-like roots.

Radices parietiformes, or tabular roots. See vol. i. p. 754.

Radices tuberosæ, or tuberous roots; roots beset with tuber-like enlargements.

Radicle, the root of an embryo; usually not separable from the hypocotyl.

Radix, the root.

Raphe, that part of the stalk of an anatropous ovule which is fused with the body of the ovule; in Diatoms, the median line on the frustule, possibly a slit.

Receptacle, of a flower; the abbreviated or flattened axis upon which the various floral members are inserted.

Reniform, kidney-shaped.

Replum, the framework, or frame-like placenta, which remains in Cruciferous and other fruits after the valves have fallen away.

Resilient, springing back, rebounding: used of fruit-stalks, stamens, &c.

Resin-duct, an intercellular passage into which resin is secreted and where it is stored.

Respiration, the term applied to the absorption by a plant of free oxygen from, and evolution of carbon dioxide into the air. It is the outward sign of a destructive oxidative process going on within the plant, by means of which latent energy is rendered available.

Revert, Reversion, a sudden return or breaking back to an ancestral form.

Revolver-flowers. See vol. ii. p. 249.

Rhizoids, the hair-like filaments of Mosses and Liverworts, which perform the functions of roots.

Rhizome, an underground (or prostrate) stem of root-like appearance from which roots and herbaceous stems arise.

Rhizomorph, name given to the curious vegetative phase of Agaricus melleus, which resembles a root.

Rhizophore, a leafless branch of peculiar construction which, in Selaginella, arises at the place where ordinary branching takes place, and bears roots at its free end.

Rhizotomoi, a guild of herbalists in ancient Greece.

Ring, Annual, the zone of wood formed from the cambium in the course of one season in a Conifer or Dicotyledon.

Ringent, gaping, as the mouth of a bilabiate corolla.

Ringing, the act of removing from a branch or trunk a circular zone of bark right down to the wood.

Root-cap, the cellular cushion produced at the apex or tip of a root.

Root-stock. Same as *rhizome.*

Rostellum, the morphological apex of the gynœceum of an Orchid; usually a beak forming the boundary between the stamen and stigma in Orchids.

Rosulate, collected in form of a rosette.

Rotate, wheel-shaped; circular and horizontally spreading.

Runner, a prostrate filiform branch which is disposed to root at the end or elsewhere.

Samara, an indehiscent winged fruit, as the *key* of the Ash or Maple.

Saprophyte, a plant which grows on dead and decaying organic matter.

Scabrous, rough to the touch.

Scape, or Scapus, a peduncle rising from the ground.

Scarious, thin, dry, and membranaceous, and not green.

Schizocarp, a polycarpellary fruit which breaks into 1-seeded portions.

Sclerotic-cell, a hard, thick-walled cell, often of irregular form; sclerotic cells may be united together into layers, or isolated in soft parenchyma.

Sclerotium, in Fungi a tuber-like mass of hyphæ, which, after remaining dormant for a while, ultimately sprouts, producing fructifications. In the Myxomycetes it is the resting-stage of the plasmodium.

Scorpioid cyme, a definite inflorescence rolled up towards one side like a crook: common in Boraginaceæ.

Scutellum, the sucker or cotyledon of a Grass embryo.

Scutiform, having the form of a shield.

Seed, the fertilized and matured ovule.

Seed-coat, the integument of the seed, formed from the investment or investments of the ovule.

Seedling, a young plant raised from a seed.

Semifrutex, or **Semi-shrub**, a shrub the shoots of which become woody at the base only, this portion alone being perennial.

Sepal, a leaf-member of the calyx.

Sepaloid, resembling a sepal.

Separation-layer. See *Absciss-layer*.

Septum, a partition; a thin wall separating compartments.

Sericeus, silky; clothed with soft straight hairs.

Serrate, of leaf-margins; beset with teeth pointing towards the apex.

Sessile, destitute of stalk, petiole, or pedicel.

Seta, a bristle; the stalk of the spore-capsule in a Moss or Liverwort.

Shoot, that portion of the plant which is differentiated into stem and leaves and bears the reproductive organs.

Sieve-cells, cells which have pores in their walls causing a sieve-like appearance; sieve-tubes.

Sieve-plates, areas in the walls of sieve-cells or sieve-tubes perforated by pores.

Sieve-tube, an articulated tube whose contiguous elements communicate by means of open pores aggregated together upon sieve-plates. The sieve-tube is the characteristic element of the phloem.

Siliqua, the fruit of a Cruciferous plant, a longish pod or seed-vessel. Cf. vol. ii. p. 432.

Sinistrorse, used of twining stems which turn from north through west to south, &c.: the opposite of *dextrorse*.

Sinuous, **Sinuate**, used of a leaf-margin which is strongly indented in a wavy manner.

Sling-fruit, a general term given to any fruit which, in virtue of the possession of contractile tissues, throws its seeds to a distance, or is itself so thrown.

Soboles, a thin creeping stem, often subterranean.

Soredium, the 'brood-body' or 'brood-bud' of a Lichen, consisting of a few algal cells wrapt round with a weft of fungal hyphæ.

Sorus, a cluster of sporangia, such as those of Ferns.

Spadiciform, like a spadix.

Spadix, a fleshy spike.

Spathe, a large bract-like sheath inclosing an inflorescence.

Spatulate, like a spatula, oblong with the lower end attenuated.

Species. Under this term may be included all individuals which possess in common such a number of characters that they may be regarded as being descended from a common ancestral form.

Spermatium, a male sexual cell which becomes free, but is unprovided with special organs of locomotion.

Spermatoplasm, the protoplasm of the male sexual cell.

Spermatoplast, a male sexual cell.

Spermatozoid, a free-swimming male sexual cell provided with cilia as organs of locomotion.

Spike, an indefinite inflorescence with flowers sessile on an elongated axis.

Spine, a sharp-pointed body possessing vascular tissue, commonly a branch or some portion of a leaf.

Sporangiole, in the Fungi; a small sporangium, usually containing few spores, and larger many-spored sporangia being also present.

Sporangiophore, that which bears sporangia; a scale bearing sporangia in Equisetum.

Sporangium, a sac within which spores are developed.

Spore, a reproductive cell which becomes free, and is capable of developing into a new individual.

Sporidium, a spore abjointed from a pro-mycelium.

Sporocarp, a fructification, often the result of a sexual act, in which spores are produced, as in Red Sea-weeds and Fungi. Also used of the sporangial receptacles of the Hydropteridæ.

Sporogonium, in Mosses; the so-called 'moss-fruit' with its appendages, consisting mainly of the capsule and seta or stalk.

Sporophyte, that stage in the life-cycle of a plant which bears the spores. Cf. *Oophyte*.

Spur, an excavated slender continuation of some portion of a flower, usually containing nectar.

Squamiform, scale-like.

Squamigerous, furnished with scales.

Stamen, the male organ in a flower, which produces pollen. It consists of the filament or stalk, and the anther, in which the pollen is contained and which is supported by the filament. The stamens collectively form the andrœcium.

Staminate, having stamens.

Staminiferous, bearing stamens.

Staminode, a sterile stamen.

Standard, in papilionaceous flowers, is the unpaired, posterior petal.

Sterigma, the tube or stalk-like branch from which conidia are abstricted.

Stigma, that portion of the pistil which receives the pollen.

Stipules, paired foliaceous appendages of the leaf-base.

Stirps cirrhosa, a tendril-bearing stem.

Stirps clathrans, a lattice-forming stem. See vol. i. p. 678.

Stirps fluctuans, a floating stem.

Stirps humifusa, a prostrate stem.

Stirps palaris, a standard-stem, *i.e.* an erect, unbranched stem.

Stirps plectens, a weaving stem. See vol. i. p. 671.

Stirps radicans, a stem which climbs by means of roots.

Stirps volubilis, a twining stem.

Stock, the parent forms from which a hybrid is derived.

Stolon, or **Stolo**, a procumbent stem which bears buds which take root; the buds are more frequent and the internodes shorter than in the runner.

Stoma, an intercellular space or pore in the epidermis which, bounded by adjustible guard-cells, forms the means of communication between the lacunæ of the plant and the outside air.

Stratification, the layering of cell-walls or starch-grains.

Stroma-starch, in certain Algæ (*e.g.* Hydrodictyon), the fine-grained starch deposited throughout the chlorophyll-body, which plays a different part in the economy of the plant from that deposited around the pyrenoid. Cf. vol. ii. p. 640.

Style, the usually attenuated prolongation of an ovary upon which the stigma is borne.

Sub-capitulum, a secondary capitulum.

Suberin, a corky substance; the substance or group of substances present in cuticularized or corky cell-walls.

Subex, a stem bearing scale-leaves.

Succulent, fleshy, pulpy.

Sucker. See *Surculus*.

Suffrutex, an under-shrub; a woody plant of quite humble growth.

Suffruticose, somewhat shrubby.

Surculus, or **Sucker**, a shoot arising from a subterranean base.

Suspensor, in Flowering Plants and in Selaginella; the filament of cells at the lower extremity of which the embryo arises.

Suture, a line of union, very frequently the line along which dehiscence also takes place.

Swarm, a social aggregate of simple organisms which live together but are not attached to any substratum.

Swarm-spore, a motile, ciliated, asexual reproductive cell destitute of a cell-membrane.

Switch-plant, a plant with reduced or wanting leaves, the shoots of which are green and subserve the functions of leaves.

Symbiosis, the association of two organisms which live together in intimate connection, both contributing to their mutual welfare.

Syncarpous, said when the carpels of a gynœceum are united.

Synconium, the fleshy excavated inflorescence of a Fig.

Synergidæ, two naked cells situated at the micropylar end of the embryo-sac, and assisting in the passage of the male cell to the egg in porogamic fertilization.

Syngenesia, the 19th class of the Linnean system.

Syngenesious, having coherent anthers.

Systole, the rhythmic contraction of a contractile vacuole.

Tagmata, aggregates of micellæ.

Tapetal cells, the layer of cells immediately external to the archesporium, and becoming latterly disorganized with the maturing of the spores (or pollen-grains).

Teleutospore, in Uredineæ, a resting-spore which on germinating gives rise to a pro-mycelium or basidium.

Tenaculum, the clasping, rosette-like clamps of Struvea, by means of which independent branches are held together.

Tendril, a filamentous branched or unbranched organ, usually sensitive to contact, by means of which a plant climbs.

Tentacle, an irritable hair or emergence on a leaf, as in Dionæa, Drosera, &c.

Terete, round, *i.e.* circular in transverse section.

Ternary hybrid, the plant resulting from crossing a hybrid with a species different from either of its parent forms.

Ternate, used of compound leaves with three leaflets, one terminal and two lateral.

Testa, the integument of a seed, often arising from the outer of the two ovular coats.

Tetrad, a group of four cells (*e.g.* spores, pollen-grains), usually arranged in the four corners of a 4-sided pyramid (tetrahedon).

Tetradynamia, the 15th class of the Linnean system.

Tetradynamous, used of stamens when there are six, of which four are longer than the other two—as in Cruciferæ.

Tetraspores, the asexual spores of Red Sea-weeds, usually aggregated in clusters of four.

Thalamus, the floral receptacle.

Thallidium, a vegetative reproductive body, especially amongst Thallophytes and Muscineæ.

Thallus, a vegetative body without differentiation into stem and leaf.

Thermal constants of vegetation. See vol. i. p. 557.

Tissue, a continuous aggregate of cells having a common origin.

Tomentose, felty or invested in tomentum.

Tomentum, dense matted investment of woolly hairs.

Torus, (1) the floral receptacle; (2) the thickening on the pit-closing membrane of a bordered pit.

Trabeculæ, folds or ridges projecting into a cell from the wall; the term also given to strings of filamentous cells bridging intercellular spaces.

Tracheids, elongated, pointed, and more or less lignified cells occurring in wood.

Transpiration, the act of exhaling aqueous vapour from foliage or other portions of plants.

Trichoblasts, fusiform hard-walled cells. Not a good term.

Trichogyne, the filamentous portion of the female sexual apparatus of a Red Sea-weed, which receives the spermatia.

Trichome, a hair-like or similar outgrowth of the epidermis.

Truncate, appearing as if cut short at the tip.

Trunk, a main stem.

Tuber, a subterranean, somewhat fleshy shoot.

Tubercle, a small excrescence.

Tumescent, becoming enlarged, distended.

Turgescence, Turgidity, the state of tension set up within a cell owing to the pressure of the osmotic cell-contents upon the elastic cell-wall.

Turion, a subterranean budding shoot, especially in perennials.

Umbel, an inflorescence in which a cluster of flower-stalks arises all from the same point.

Unguiculate, narrowed at the base into a claw: used of petals.

Urceolate, hollow and contracted at or below the mouth like an urn.

Uredospore. See vol. ii. p. 686.

Utricle, an archaic term for a parenchyma-cell.

Vacuole, a cavity in the protoplasm containing cell-sap.

Vagina, the sheathing portion of a leaf-base.

Valvate, having valves; opening by valves; also, used of the arrangement of the parts of a flower-bud when they just meet but do not overlap. Cf. vol. ii. p. 210.

Valve, (1) in flowering plants, the pieces into which a capsule breaks are termed valves; also the movable flaps in the dehiscence of anthers; (2) in Diatoms, the valves are the halves of the silicified membrane or shell, also called *frustules*.

Variegation, a term employed to designate the disposition of two or more colours in the petals, leaves, and other parts of plants.

Vascular bundle, a continuous strand of vascular tissue, consisting either of xylem or phloem, or of both. Not infrequently sclerenchymatous elements are associated with the bundle, when it is termed a fibro-vascular bundle.

Vascular elements, cells or vessels whose main function is the distribution of water or formed food-substances. The chief of them are the vessels and tracheids of the wood, and the sieve-tubes of the phloem.

Velum, in Isoëtes; the indusium-like membrane which covers the sporangium.

Velum partiale, in Hymenomycetes; the veil stretching from the stipe to the edge of the pileus. It often remains as the annulus.

Velum universale, in Hymenomycetes; the membranous wrapper inclosing the whole fructification.

Venation, the arrangement or pattern of the vascular bundles in a leaf.

Ventral canal-cell, the small cell which is cut off from the central cell of an archegonium immediately below the neck.

Ventricose, unequally swollen.

Vernation, the arrangement of the parts in the bud, especially a vegetative bud.

Verrucose, covered with warts.

Versatile, turning freely on its support.

Verticillate, arranged in a whorl.

Vessel, a tube consisting of cells which have become confluent by the partial or complete absorption of the intervening walls. They are common in the wood of Angiosperms.

Viviparous, term applied to plants the seeds of which germinate whilst still on the parent plant.

Volva, same as *velum universale*.

Whorl, a series of appendages arranged in a circle around an axis.

Witches' Broom, a form of gall found on the Silver Fir and other Conifers; sometimes applied to the bird's-nest-like hypertrophies on the Birch, &c.

Wood, the hard, lignified portion of the vascular tissue otherwise known as the *xylem*. It contains tracheids, woody fibres, and wood parenchyma, though not all of these are necessarily found in the wood of any given plant.

Xenogamy, pollination between flowers growing on different individuals of the same species.

Xylem, the woody portion of vascular tissue. See *Wood*.

Zooglœa, a solid gelatinous colony of Bacterial organisms.

Zygomorphic, applied to flowers which are symmetrical about one plane only, or can be cut into similar halves in only one plane.

Zygospore, a spore formed by the union of two gametes.

Zygote, a general term for the product of fusion of two gametes.

Zygozoospore, the motile stage of a zygote, the product of fusion of two motile gametes.

INDEX.

The page numbers in bolder type indicate illustrations.

B.

C.

D.

E.

F.

H.

I.

J.

K.

L.

M.

N.

O.

P.

Q.

S.

T.

U.

V.

W.

X.

Y.

Z.

END OF VOL. II.

THE

NATURAL HISTORY OF PLANTS

THE

NATURAL HISTORY OF PLANTS

THEIR FORMS, GROWTH, REPRODUCTION, AND DISTRIBUTION

FROM THE GERMAN OF

ANTON KERNER VON MARILAUN

PROFESSOR OF BOTANY IN THE UNIVERSITY OF VIENNA

TRANSLATED AND EDITED

BY

F. W. OLIVER, M.A., D.Sc.

QUAIN PROFESSOR OF BOTANY IN UNIVERSITY COLLEGE, LONDON

WITH THE ASSISTANCE OF

MARIAN BUSK, B.Sc. AND MARY F. EWART, B.Sc.

WITH ABOUT 2000 ORIGINAL WOODCUT ILLUSTRATIONS AND SIXTEEN PLATES IN COLOURS

VOLUME II.

THE HISTORY OF PLANTS

LONDON

BLACKIE & SON, LIMITED, 50 OLD BAILEY, E.C.

GLASGOW AND DUBLIN

EDITOR'S PREFATORY NOTE.

With this, the second and concluding volume of *The Natural History of Plants*, a brief statement and explanation of my position as editor is imperative. As stated in my note to Volume I. the English text there followed that of the original with considerable fidelity. In the second volume I have less consistently followed this course. Throughout I have not hesitated to add or substitute new matter, though no overt indication of such departure from the original is given either by different type or otherwise. It is needless to explain that these changes are only such as the advance of botanical knowledge has rendered necessary since the original was written, and that I have never desired to depart from the intention of the author. To the specialist these modifications will be from time to time apparent; the general reader will perhaps treat me with indulgence should he think that in this matter my judgment has been at fault. Though changes occur throughout the volume, I have preserved intact the main conclusions of the author and the facts upon which they are based. To have altered these in any way, even had I been so minded, would have been inconsistent with the duties of an editor and translator. But in the purely systematic portion of the work I have been restrained by no such scruples. Professor Kerner himself regarded that portion of his work as but tentative, and as it was difficult to merely modify, the whole of this portion has been written *de novo*, from the Thallophytes to the end of the Gymnosperms (pp. 616–728), and in part the Monocotyledons. The exigencies of the serial issue of *The Natural History of Plants* alone has prevented the re-cast of the Dicotyledons, which stand with little modification as in the original. For the portion dealing with the class *Gamophyceæ* up to the end of the *Conjugatæ* (pp. 627–659), I am indebted to my colleague, Mr. A. G. Tansley of University College, who has devoted

considerable attention to the group in question. To him I now offer my hearty thanks. The glossary of botanical terms makes claim neither to completeness nor originality. Though a large number of the definitions and explanations have been written specially for this book, I have never hesitated to lay published sources under contribution. The laborious task of constructing the index has fallen to Mr. George Brebner, and to him is due the gratitude of such as gain through it direct and ready access to the body of the work.

F. W. O.

CONTENTS OF VOLUME SECOND.

INTRODUCTION.

THE GENESIS OF PLANT-OFFSPRING.

THE HISTORY OF SPECIES.

CLASSIFICATION OF PLANTS FOLLOWED IN THIS WORK.

ILLUSTRATIONS.

FROM ORIGINAL DRAWINGS BY E. HEYN, E. v. RANSONNET, J. SEELOS, F. TEUCHMANN, O. WINKLER, AND OTHERS.

COLOURED PLATES.

ILLUSTRATIONS IN THE TEXT.

THE HISTORY OF PLANTS